The Dissertation Committee for Bryant Cashious Silbaugh certifies that this is the approved version of the following dissertation:

Effects of Lag Schedules on Vocal Mand Variability and Challenging Behavior during Functional Communication Training

Terry Falcomata, Supervisor

Mark O'Reilly

Christina Fragale

Micheal Sandbank

Russell Lang

Effects of Lag Schedules on Vocal Mand Variability and Challenging Behavior during Functional Communication Training

By

Bryant Cashious Silbaugh, B.A.; M.A.

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Dedication

I dedicate this dissertation to the children and families who volunteered their time to the pursuit of a scientific understanding of behavior and its application in the assessment and treatment of autism spectrum disorder.

I also dedicate this dissertation to Jocelyn Walker. By providing me with mentorship and a safe and encouraging place of employment at a difficult time in my teenage years, Jocelyn dramatically changed the course of my life and put me on a path to success. I hope that I have many opportunities to do the same for others.

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Bryant Cashious Silbaugh, Ph.D.

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SUPERVISOR: Terry S. Falcomata

Reinforcing multiple mand topographies or modalities during functional communication training (FCT) may increase the persistence of manding during challenges to treatment. However, validated procedures that reinforce the use of multiple mand topographies during FCT are lacking. Prior research demonstrated that FCT with a lag schedule of reinforcement reduced challenging behavior and increased non-vocal mand variability across modalities in individuals with autism. This finding suggests similar procedures may have similar effects on challenging behavior and vocal and/or sign manding. Also, studies have shown that lag schedules following response prompting and/or prompt fading can increase variability in vocalizations, tacts, and intraverbals. Therefore, the current study evaluated the effects of response prompting procedures and a lag schedule of reinforcement on topographical mand variability and challenging behavior during FCT. The results suggest that lag schedules can reinforce topographical mand variability during FCT following the fading or elimination of response prompts. This finding warrants study of the effects of these procedures on the resurgence of manding and challenging behavior following treatment with FCT in children with autism. Limitations of the current study and directions for future research are discussed.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

Behavior is the measurable movement of a part of an organism which includes interaction with the environment, including those movements which can and cannot be observed by others (Catania, 2013; Donahoe & Palmer, 2004; Johnston & Pennypacker, 1993; Skinner, 1938). Operant behavior is movement(s) of the organism selected by environmental consequences (Skinner, 1981) and defined by a four-term contingency consisting of a motivating operation, a class of discriminative stimuli, one or more responses, and a controlling class of consequent stimuli commonly referred to as its function (Michael, 2004).

The label "operant", sometimes used interchangeably with functional response class, is given to one or more responses when the probability that future instances will repeat is modified by a common class of consequent stimuli they produced in the past (Catania, 1973; Catania, 2013). Environmental conditions permitting, dimensions of the operant such as duration, force, or topography (i.e., form or structure) can vary across instances of the response class emitted over time (Skinner, 1938). For example, to obtain a teacher's attention a student can stand up and walk to the teacher, raise their hand, or call out "I know the answer!"

A common class of consequent stimuli can also increase the probability that future instances of the operant will vary (Page & Neuringer, 1985). Operant variability is necessary for the survival of organisms (Sidman, 1960) due to its role in the development of individual repertoires through operant selection (Skinner, 1981). In education, no student learning would occur without it (Skinner, 1968). When challenging behavior (e.g., hitting, yelling, biting) commonly displayed by children with autism spectrum disorder (ASD) or other developmental disorders (DD) is treated as operant behavior, procedures validated by applied behavior analysis (ABA) researchers such as functional communication training (FCT; Carr & Durand, 1985) can replace challenging behavior by differentially reinforcing the repeated emission of an alternative socially appropriate topography.

FCT is a function-based treatment (Dixon, Vogel, & Tarbox, 2012) for challenging behavior of individuals with DD, with extensive empirical support (e.g., Kurtz, Boelter, Jarmolowicz, Chin, & Hagopian, 2011). Typically, when an individual is referred for treatment of challenging behavior, a functional behavior assessment (FBA) using indirect (e.g., interview) and direct assessment (i.e., observation and measurement) is conducted to guide treatment development (O'Neill et al., 1997). FBA attempts to answer the question, "what is the function of this behavior?" because the answer can guide the practitioner to take a best-practice approach of selecting an effective function-based treatment (Dixon et al., 2012).

Direct assessment (DA) is conducted in the environment where the behavior occurs and can help identify controlling variables (i.e., antecedents and consequences). The results of the DA guide the practitioner to hypothesize the functions of the behavior, which can be experimentally validated in a functional analysis (FA; Iwata et al., 1982/1994; Iwata & Dozier, 2008) using single-subject design experimental methodology

(Kennedy, 2005) and visual analysis (Poling, Methot, & LeSage, 1995). If visual analysis identifies a clear functional relation between challenging behavior and a class of reinforcing stimuli (e.g., attention, escape) the practitioner can proceed with FCT by incorporating the controlling variables for the behavior into treatment. There are multiple procedural variations of FCT (Rooker, Jessel, Kurtz & Hagopian, 2013). Typically FCT consists of selecting a socially appropriate response topography, or “mand”, to produce the reinforcer identified in the FA, while the reinforcer is withheld for all instances of challenging behavior.

The mand is a verbal operant under the control of an establishing operation (EO; Michael, 1988) and reinforced through mediation of a trained verbal audience by consequences specified by the form of the mand (Skinner, 1957). In the case of the mand, the EO is an antecedent stimulus, operation, or condition that (a) momentarily increases dimensional quantities (e.g., rate, force) and topographies of the mand and (b) momentarily increases the value or effectiveness of reinforcers produced by the mand (Miguel, 2013).

Mands can be classified as selection-based or topography-based (Michael, 1985). Selection-based mands affect listener-mediated reinforcement by selecting a stimulus in the environment. The topography is constant across a range of stimuli. Different reinforcers are provided by the listener depending on the particular stimulus selected by the speaker. For example, a non-vocal child may give an adult a picture of a cup of milk in exchange for milk to drink, or the same child may give a picture of a juice box in exchange for juice. The topography of the response (card exchange) is invariant, but stimulus selections vary and on the basis of the stimuli selected the listener provides different consequences. In contrast, topography-based mands affect listener-mediated reinforcement by varying the form of the response (e.g., signing milk and receiving milk, saying “juice please” and receiving juice). Thus, varying selections across concurrently available stimuli for selection-based manding, and varying the form of the mand for topography-based manding, are necessary prerequisite skills for the development of verbal repertoires. Yet, since the concept of the verbal operant was developed (Skinner, 1957), research on variables within the operant paradigm that increase mand variability in individuals with language delays or deficits (e.g.,) or ASD is highly limited (Bernstein & Sturmey, 2008; Betz, Higbee, Kelley, Sellers, & Pollard, 2011; Broadhead, Higbee, Gerencser, & Akers, 2016; Carr & Kologinsky, 1983; Drasgow, Marti, Chezan, Wolfe, & Halle, 2015; Duker & Lent, 1991; Sellers, Kelley, Higbee, & Wolfe, 2015), and no studies of mand variability as a dependent variable (as opposed to novel responding or generalization) have addressed the distinction between selection-based and topography-based manding. .

During FCT, individuals may emit an appropriate response topography under the control of the same consequences that maintain challenging behavior, which can then be differentially reinforced to replace challenging topographies (e.g., Grow, Kelley, Roane, & Shillingsburg, 2008). Otherwise, a new selection-based (e.g., picture exchange or microswitch press; e.g., Winborn, Wacker, Richman, Asmus, & Geier, 2002) or topography-based (e.g., sign or vocal; e.g., Volkert, Lerman, Call, & Trosclair-Lasserre, 2009) response must be taught. For example, a child's hitting others may be maintained by socially-mediated negative reinforcement in the form of terminating task demands. During FCT, termination of task demands is withheld for instances of hitting, and delivered contingent on manding "break please". If "break please" is not a response variation in their repertoire prior to FCT, it would be trained using prompts, prompt fading, and differential reinforcement. Decades of empirical research have yielded best practices and practical guidelines for the use of FCT (Tiger, Hanley & Bruzek, 2008). However additional research on variables that predict and control recurrences of variations in functionally equivalent response class members during disruptions to treatment is needed to better equip practitioners to prevent relapse of challenging behavior.

Disruptions in treatment that evoke the recurrence of challenging behavior, referred to as relapse, or failure to maintain and/or generalize (Lit & Mace, 2015), consist of typical environmental changes in applied settings that deviate from conditions associated with a treatment plan. Examples include (a) extinction (i.e., withholding of reinforcement for a mand previously taught to replace challenging behavior), (b) a change in an aspect of task demands presented to a learner when challenging behavior was maintained by termination of task demands, (c) the temporary unavailability of augmentative alternative communication systems (e.g. icon not available for exchange), and (d) the concurrent availability of reinforcement for mands and challenging behavior

(Wacker, et al., 2011). The temporary recurrence of challenging topographies of behavior that result from the subsequent withholding of reinforcement by a trained audience or a dramatically thinned reinforcement schedule as the learner emits the appropriate response has been referred to as a type of resurgence (e.g., Volkert et al., 2009; Wacker et al., 2011). For example, consider challenging behavior reinforced by termination of task demands. During FCT, when the learner emits challenging behavior, task demands continue, but when the learner emits an appropriate mand topography "break please", the task demand is terminated. Following successful replacement of challenging response topographies with the response "break please", the learner may encounter someone at home or in the community who withholds reinforcement when the response repeatedly occurs, resulting in subsequent resurgence of challenging response topographies.

Since the earliest studies that demonstrated the phenomenon (e.g., Carey, 1951; Epstein, 1983), resurgence has been defined in different ways, including "a procedure, outcome, and process by which previously suppressed responding recurs following discontinuation of reinforcement for an alternative response" (St. Peter, 2015). Resurgence has been shown to be conserved across species (e.g., Epstein, 1983; Reed & Morgan, 2006; Wacker et al., 2013), demonstrated across multiple subjects, settings, responses, and reinforcement schedules (St. Peter, 2015); and is thought to be involved in the emergence of novel or creative behavior (e.g., Shahan & Chase, 2002). Yet, applied research on resurgence is largely limited to individuals with ASD or other DD (St. Peter, 2015). Resurgence should be considered by practitioners concerned with education and clinical practice, because as reviewed by St. Peter, (a) resurgence is robust and generalizable across species and functional domains, (b) complex responses and sequences of responses may resurge, (c) the environmental arrangement used to demonstrate resurgence corresponds closely to common sequences of behavioral intervention (e.g., FCT), (d) incorporating procedures that produce resurgence of desirable behavior may be used to promote persistence in problem solving or resistance to disruptions in treatment, (e) a learner's reinforcement history can impact resurgence, and (f) the topography of alternative responses incorporated into a response class may influence resurgence. The variables in an organism's history and current environment that influence resurgence in humans have only begun to be explored by translational and applied researchers, and they are highly complex (e.g., see Lit & Mace, 2015). Procedures for attenuating resurgence during treatment disruptions, with some empirical support, include (a) reinforcing the alternative response in a context not previously associated with reinforcement for challenging behavior (e.g., Mace et al., 2010) and (b) post-DRA delivery of known reinforcing stimuli independent of responding (e.g., Marsteller & St. Peter, 2014). Alternatively, other researchers have focused more on the concept of the response class and procedures for teaching multiple alternative responses during treatment.

Hagopian, Fisher, Sullivan, Acquisto, and LeBlanc (1998) hypothesized that breakdowns in manding following FCT may be due to incorporation of a new mand topography into the same operant response class as challenging behavior. They reasoned that if challenging topographies are not extinguished prior to reinforcing the alternative mand, challenging topographies may also be reinforced even though they don't produce the reinforcer directly because reinforcement may increase or maintain the entire set of topographies that define the operant. This process may explain why in some cases FCT results in resurgence during reinforcement schedule thinning (see Rooker et al., 2013 for a review) which initially functions as a challenge to treatment (Wacker, et al., 2011) that is used to reduce levels of manding to those tolerable to caregivers. That is, challenging response topographies may resurge during treatment disruption because they were indirectly reinforced during FCT (Wacker et al., 2013; Mace et al., 2010). One potential solution to this problem is to strategically (a) program against resurgence of challenging topographies and (b) program for resurgence of appropriate manding (Falcomata & Wacker, 2012; Hoffman & Falcomata, 2014) by teaching multiple appropriate mand topographies or multiple modalities of selection-based responding during FCT so that disruptions in treatment evoke resurgence of multiple appropriate alternative mands incompatible with challenging behavior (e.g., Berg et al., 2015; Lambert, Bloom, Samaha, Dayton, & Rodewald, 2015).

Lambert et al (2015) conducted a translational study in which they used a two-component multiple schedule to compare the rate and pattern of resurgence following standard DRA and a serial DRA treatment for three adults with DD. The dependent variable was responding to switch devices and reinforcers were edibles identified by stimulus preference assessment. In each component, control and test, a reinforcement phase was followed by an elimination phase, and then a resurgence phase. For both components, during the reinforcement phase a target response to a single switch was reinforced on an FR 1 schedule. Again for both components, in the elimination phase, the target response was placed on extinction and responses to an alternative switch was reinforced on an FR 1 schedule. In the control component (i.e., standard DRA), alternative responding to a single new switch was reinforced. In the test component (i.e., serial DRA), after alternative responding to a new switch was differentially reinforced in one subphase, alternative responding to a second switch was differentially reinforced in a second subphase, and alternative responding to a third switch was differentially reinforced in third subphase. During the resurgence phase, all responding was placed on extinction in the presence of the switches corresponding to the component. The results showed that (a) lower relative and absolute rates of target response resurgence was associated with a larger response repertoire established with serial DRA, (b) at least one alternative response emerged prior to the recurrence of the target response, and (c) the order of alternative responses emitted under extinction progressed from most to least recently trained (i.e., reversion) for two of three participants.

Alternatively, schedules of reinforcement that select for operant variability may be used to simultaneously teach and/or strengthen multiple mand topographies or selection-based responses to multiple mand modalities during FCT (Adami, Falcomata, Muething, & Hoffman, 2017). Furthermore, when multiple response class members are emitted in a temporally predictable order, known as a response class hierarchy (RCH;

Baer, 1982), the likelihood of resurgence of specific topographies (i.e., challenging behavior or appropriate mands) may be controlled by modifying temporal relations or relative response strength as indicated by the structure of the hierarchy. Such an approach goes beyond replacing challenging topographies with appropriate mand topographies by (a) directly targeting operant variability to enhance the adaptive use of manding, (b) minimizing contingencies in the environment that maintain restricted and repetitive verbal behavior, and (c) possibly enhancing the social validity of FCT by teaching the skill of advocating for one's self through more assertive but safe and appropriate means of requesting important forms of reinforcement (Bloom & Lambert, 2015).

Variability is a dimension of operant behavior like rate, latency and magnitude (see Neuringer, 2012 for a review) that can be reinforced and brought under discriminative control (Page & Neuringer, 1985). Lag schedules of reinforcement increase variant responding by differentially reinforcing a response or response sequence if it differs from N preceding responses or response sequences, with N equal to the value of the lag (Page & Neuringer, 1985). For example, under a Lag 2 schedule of reinforcement a response is reinforced if it differs on some specified dimension from the immediately preceding two responses. Lag schedules may replace repetitive and stereotyped behavior with adaptive behavioral variability (Rodriguez & Thompson, 2015). For example, lag schedules have been used alone and in combination with other procedures to reinforce variability in clinically relevant verbal (e.g., Lee & Sturmey,

2002) and non-verbal (e.g., Silbaugh & Falcomata, 2016) behavior of children with ASD in applied settings (for a review, see Wolf, Slocum & Kunnavatana, 2014).

Adami et al (2017) conducted the first investigation of the use of lag schedules in the treatment of challenging behavior. They embedded lag schedules into FCT for two individuals with ASD to differentially reinforce variant non-vocal selection-based mands across stimuli for three modalities (i.e., tablet, microswitch, and a picture icon). An instance of variant manding was selection of a mand modality that differed from the last mand modality selected within the session, and rates of manding and challenging behavior were compared between FCT conditions with Lag 0 or Lag 1 schedules of reinforcement while challenging behavior was extinguished. For both participants, FCT Lag 0 (i.e., any mand modality selection was reinforced) produced efficient rates of invariant manding that replaced challenging behavior. However, FCT under the Lag 1 schedule both replaced challenging behavior and produced efficient rates of variant manding across modalities. Falcomata, Muething, Silbaugh, Adami, & Shpall (in preparation) further evaluated the effects of FCT with lag schedules for two younger children with ASD. During baseline, challenging behavior was reinforced in a manner analogous to the relevant test condition from the preceding functional analysis. During FCT Lag, the value of the lag schedule (i.e., Lag 1 through Lag 5) was increased across sessions in the context of five manding modality stimuli. Consistent with the findings from Adami et al., efficient rates of variant manding replaced challenging behavior under FCT Lag. In addition, rates of challenging behavior remained at low or zero levels as the value of the lag schedule was increased from Lag 1 to Lag 5 (i.e., an increase in the intermittency of reinforcement contacted by variant manding), and maintenance of variant responding was assessed and demonstrated for one participant under FCT Lag 0 following a two-week period without treatment. The latter finding suggests FCT combined with lag schedules may establish variant manding that is resistant to challenges to treatment such as changes in listener-mediated contingencies for manding.

In an unpublished pilot study, our group evaluated the effects of FCT with lag schedules on rates of topographical vocal mand variability and escape maintained disruptive behavior in a young boy with ASD. The treatment was evaluated following a brief pre-treatment vocal mand topography training procedure. The training consisted of three consecutive 10-trial sessions and across sessions a different topography (i.e., “no work” “no thanks” or “no more”) was reinforced. The treatment evaluation compared the effects of FCT Lag 0, FCT Lag 1, and FCT Lag 2 on rates of disruptive behavior, overall manding, and variant manding when challenging behavior was on extinction. FCT combined with Lag 1 or Lag 2 schedules failed to replace disruptive behavior with vocal mand variability. However, FCT on an FR1 schedule of reinforcement was effective at replacing disruptive behavior with topographically invariant vocal manding. The results of this study highlighted the need for additional research on the reinforcement of mand variability to identify procedures compatible with FCT.

Silbaugh, Falcomata, and Ferguson (submitted) evaluated the effects of a lag schedule combined with a progressive time delay on topographical variability in vocal manding and mand response class structure in two young children with ASD. Prior to the treatment evaluation, a play-based mand variability assessment was conducted to (a) identify two topographically invariant vocal mands in the participants' repertoires, and (b) select two vocal mand topographies to subsequently incorporate into each mand. Reinforcement in the form of access to the requested item was delivered for 25 s contingent on the target response in both conditions. During the Lag 0 condition, reinforcement was delivered contingent on any target vocal mand topography emitted independently. During the Lag 1 condition, reinforcement was delivered contingent on variant target vocal mand topographies prompted or emitted independently. A variant vocal mand topography was one that differed from the immediately preceding vocal mand topography emitted within the session. The Lag 1 schedule of positive reinforcement was combined with a progressive time delay (TD). The TD procedure consisted of model prompting the emission of a variant target vocal mand topography if the participant did not emit an independent variant vocal mand topography before the end of the TD for a given trial (i.e., instance of the programmed EO). The first session of the first Lag 1 condition began with a 2-s TD. Every 6 consecutive trials that an independent variant vocal mand topography was not emitted within the TD, the length of the TD was increased by 2 s. The results demonstrated that a lag schedule of positive reinforcement with progressive time delay reinforced rates of topographical vocal mand variability for both participants. The results of the relative latency-based RCH assessment suggested that the treatment also established and/or expanded mand response class hierarchies with multiple vocal mand topographies, some of which were not directly trained. These findings provided support for the generality of the effects of lag schedules across ages, learning histories, and mand modalities, and warranted an investigation into their effects on topographical variability in sign manding.

Silbaugh and Falcomata (in preparation) evaluated the effects of a Lag 1 schedule of positive reinforcement combined with a progressive time delay on the acquisition of sign manding, sign mand variability, and mand response class structure in a young boy with ASD. After a brief pre-treatment training demonstrated the participant rapidly acquired a novel arbitrary sign for a tangible reinforcer, the treatment evaluation began. During the treatment evaluation, rates of overall sign manding and variant sign manding were compared between Lag 0 and Lag 1 conditions using the same reinforcer from pre-treatment training. During Lag 0, the experimenter reinforced any independent sign with 20 s access to the programmed reinforcer. During Lag 1, the experimenter utilized a progressive time delay procedure to differentially reinforce target sign mand topographies (i.e., signs for “want” “toy” and “playdoh”). The results of the treatment evaluation showed that the participant emitted elevated rates of overall and variant manding when manding contacted the lag schedule, and suggested the participant acquired a mand response class hierarchy consisting of five different sign mand topographies.

In summary, an operant behavior consists of one or more response topographies selected by a common class of consequent stimuli to either repeat or vary in the future under similar conditions of selection. The mand is a type of verbal operant which requires the skill of varying across the stimuli selected or across topographies to adapt to changes in the contingencies of reinforcement mediated by a verbal audience. When topographical variations are emitted in a temporally predictable order, they comprise a RCH. These properties of operant behavior have significant clinical implications for the treatment of challenging behavior. Specifically, environments may be arranged to strengthen operant variability for the purpose of reducing the recurrence of challenging behavior after treatment begins. There is convergent empirical evidence that lag schedules can be used in applied settings for individuals with ASD (a) in combination with FCT to reduce challenging behavior, (b) to teach or reinforce mand variability, and (c) to modify mand RCH. Therefore, to further the development of technology that may be used to program for the resurgence of appropriate mands following FCT, the purpose of the proposed study is to evaluate the effects of FCT combined with a lag schedule and response prompting on rates of challenging behavior and topographical mand variability in children with ASD.

Chapter 2: A Synthesis of Methods for Characterizing the Response Class Structure of Challenging Behavior in Individuals with Autism or Intellectual Disability

Operant response classes can be classified on the basis of topography or function (Catania, 2013). Occurrences of a single response form across two or more contexts resulting in different consequences comprises a topographical response class. For example, one might press a button to turn off a smoke alarm, or to obtain a soda from a vending machine. Two or more responses that differ along a dimension (e.g., topography, force, or rate) but produce and are modified in response strength by the same consequent stimuli comprise a functional response class (i.e., an operant; Catania, 1973; Catania, 2013). For example, one can obtain an item high on a shelf at the supermarket by standing on a lower shelf, or asking a taller customer for help.

Members of a functional response class can substitute for one another (e.g., Carr & Durand, 1985), and a history of differential reinforcement can lead select members to occur more frequently than others (Grow et al., 2008; Parrish et al., 1986). Changes in parameters (Beavers, Iwata, & Gregory, 2014) or schedules (Mendres & Borrero, 2010) of reinforcement (i.e., response-reinforcer relations; Beavers et al., 2014) selective for one or more members of a functional response class can differentially alter the relative probabilities of its members. Relative probabilities of class members may also be attributed to histories of punishment (i.e., response-punisher relations; Lalli, Mace, Wohn, and Livesey, 1995) or response effort in terms of the force applied when responding (e.g., response-response relations; Shabani, Carr, & Petursdottir, 2009). When response class members occur in a relatively predictable temporal order and their relative response probabilities can be classified hierarchically, the operant is called a response-class hierarchy (RCH; Baer, 1982).

The RCH concept likely has broad clinical and theoretical implications for behavior analysis and its application. There are at least five reasons why technology related to the RCH concept should be considered by practitioners. First, the hierarchical organization of a RCH may influence the recurrence of previously extinguished topographies of challenging behavior when the entire response class contacts extinction (e.g., Lieving, Hagopian, Long, & O'Connor, 2004). Second, in some cases the results of functional analysis (FA) can mask more severe topographies comprising a RCH when reinforcement during test conditions is maximized by less severe topographies (e.g., Magee & Ellis, 2000; Richman, Wacker, Asmus, Casey, & Andelman, 1999). Third, subsequent to the FA, previously unidentified severe topographies may occur unexpectedly during treatment integrity failures. As a result, clinically contraindicated revisions of the treatment plan may be implemented based on the erroneous assumption that more severe topographies serve another function or that the original challenging topographies have changed functions. Forth, functional communication training (FCT) replaces challenging topographies with socially acceptable topographies (Carr & Durand, 1985). The frequency of severe topographies of a RCH may be reduced or eliminated during FCT by differentially reinforcing presumably less effortful topographies within the response class (DeRosa, Roane, Doyle, & McCarthy, 2013; Dracobly & Smith, 2012). However, differentially reinforcing desirable or less effortful members of a response class of challenging behavior may both reduce current levels and increase the response strength or persistence of severe challenging topographies (Lieving et al., 2004; Mace et al., 2010; Wacker et al., 2013; Berg et al., 2015). Fifth, the role of RCHs in other skill domains such as academics is likely important for instruction but is largely unknown.

Although over 30 years have passed since the RCH concept was described (Baer, 1982), limited empirical scrutiny and lack of cohesive examination of the literature may have limited the use of related behavior change procedures and assessments by practitioners. Researchers have made progress in the development of a variety of experimental analyses designed specifically to assess multiple topographies that comprise RCH in individuals with challenging behavior (e.g, Lalli, et al., 1995). Additionally, researchers have developed assessments of mild challenging topographies (e.g., Herscovitch, Roscoe, Libby, Bourret, & Ahearn, 2009) or innocuous topographies (e.g., Langdon, Carr, & Own-DeSchryver, 2008), called precursors, that reliably occur early in episodes of escalating challenging behavior, for the purpose of designing interventions that prevent escalation. Although the original purpose of precursor assessment methods may have been to identify the most probable member(s) of a functional response class (Smith & Churchill, 2002), such methods have been described as relevant to characterizing RCH as well (e.g., Dracobly & Smith, 2012; Herscovitch, Roscoe, Libby, Bourret, & Ahearn, 2009).

A systematic synthesis of research on methods used to identify and characterize the response class structure of challenging behavior could clarify the state of the technology and the utility of the RCH concept in application. Beyond summarizing basic participant and study characteristics, the purposes of this systematic synthesis were to (a) quantify, summarize, and describe methods used to identify and characterize precursors or RCHs, (b) suggest potential benefits and limitations of each assessment type, (c) develop tentative practice guidelines, and (d) suggest future lines of research.

METHOD

Search Procedures

A systematic multi-step search process using electronic databases and Google Scholar was used to identify studies subsequently screened for inclusion. First, a search for peer-reviewed journal articles written in English was conducted using EBSCO across PsycINFO, Medline, and Education Resources Information Center (ERIC) electronic databases with the search terms “response class hierarchy” and “precursor* AND behavior”. This search yielded a total of 42 studies and five met inclusion criteria. Next, the electronic databases of individual journals that publish behavior analytic research but may not be available through EBSCO (e.g., *The Psychological Record, Journal of The Experimental Analysis of Behavior, Behavior Analysis in Practice, Journal of Applied Behavior Analysis)* were searched using the same search terms, which yielded 184 studies. Nine of these studies met inclusion criteria. Next, the titles of included studies and references cited were entered into Google Scholar to identify additional studies, and one met inclusion criteria. In summary, the search and screening process completed in April of 2016 yielded 15 studies that met inclusion criteria.

Inclusion and Exclusion Criteria

A study was included if it (a) used methods to identify or characterize precursors or a RCH of challenging behavior in an applied setting, and (b) used single-subject experimental design methodology. A study was excluded (a) if response covariance was assessed across operants or if a target response was non-verbal (e.g., Parrish, et al., 1986), (b) the study focused on the evaluation of the effects of FCT on response covariation, or (c) responses believed to comprise the RCH varied not in topography (i.e., typically a defining feature of RCH; Mace, Pratt, Prager, & Pritchard, 2011) but in the stimuli selected (e.g., Beavers et al., 2014). Lack of an adequate visual display of the data to allow for RCH assessment was the basis for excluding one study (Drasgow, Martin, Chezan, Wolfe, & Halle, 2015). Precursor assessment studies were included if they provided graphed data of precursors and severe topographies in a manner that enabled visual analysis for the purpose of identifying and distinguishing RCHs from response chains or precurrent responses (Fahmie & Iwata, 2011). Studies excluded by this last criterion included Najdowski, Wallace, Ellsworth, MacAleese, and Cleveland (2008), Albin, O'Brien, and Horner (1995), and Hagopian, Paclowskyj, and Kuhn (2005).

Data Extraction

A coding guide was developed to extract data on participant and study characteristics. Treatment evaluation data were excluded. Data were extracted only from those studies or aspects of studies that focused on assessment or experimental analysis of a RCH or precursors.

Dependent Variables

For participant characteristics, data were collected on age and sex, diagnoses, and challenging behavior. For study characteristics, data were collected on settings, assessment of dependent and independent variable integrity, RCH or precursor methods, and the use of assessment or experimental analysis results to inform a treatment evaluation.

Multiple variations of methods for identifying and characterizing RCH and precursors have been developed by researchers, but no classification system existed for distinguishing between the variations in a manner conducive to synthesis. Therefore, a distinct classification was given to each variation based on its defining features, which in some cases differed somewhat from the classification or name given to the assessment by the authors (i.e., defining features were added to the authors' classification) but allowed for data collection on types of RCH or precursor methods.

Methods Classification

A method was classified as an *indirect assessment* if it consisted of interviewing respondents (e.g., Herscovitch et al., 2009), or a *direct assessment* if data were collected through observation only (e.g., Dracobly & Smith, 2012, Study 1) or the method was used as a secondary analysis of data collected during an FA or systematic treatment evaluation (e.g., Richman et al., 1999). A method was classified as a *structured consequence-based assessment* if antecedents and consequences were manipulated (a) and visual analysis was not used to identify the RCH, but data were displayed in a bar graph for visual inspection of the temporal relations between response topographies as indicated by absolute latencies (e.g., Lalli et al., 1995), (b) data were displayed in equal interval line graphs, not to identify functions of behavior, but to characterize the suspected RCH (e.g., Lieving et al., 2004), (c) or to assess covariation among more and less severe response class members (e.g., Shukla-Mehta & Albin, 2003), or (d) to assess covariation among precursors and challenging topographies (e.g., Langdon et al., 2008). A method was classified as an *experimental analysis* if antecedents and consequences were manipulated, and data were displayed in an equal-interval line graph for visual analysis to identify the precursor by its functional relation to programmed consequences (e.g., Fritz, Iwata, Hammon, & Bloom, 2013, study 2), or to evaluate the function of both mild and severe challenging behavior (e.g., Dracobly & Smith, 2012, study 2).

RESULTS

Chapter 2 continues with a report of the results consisting of a summary of participant and study characteristics and a description of the methods in detail. This chapter concludes with recommendations for practitioners and suggestions for future research.

Most studies were published in the *Journal of Applied Behavior Analysis* (n = 10; 66%). One study (7%) was published in each of the following journals: *Behavior Modification*, *The Psychological Record*, *Behavior Analyst Today*, the *European Journal of Behavior Analysis*, and the *Journal of Physical and Developmental Disabilities*.

Participant Characteristics

Forty-two participants were included in the studies reviewed. Twenty-five participants were male (60%) and 17 were female (40%). The mean age of the participants was 16-years-old (range, 3 - 54). Most participants (n=21; 50%) were identified as having an intellectual disability or mental retardation (mild intellectual disability or moderate mental retardation, n=11, 26%; severe to profound intellectual disability or mental retardation, n=10, 24%), followed by individuals diagnosed with autism (n= 16; 38%). Aggression was the most frequently targeted challenging behavior for 50% of participants (n=21), followed by self-injurious behavior (n=19; 45%), different types of property destruction (n=7; 17%), different types of negative or inappropriate vocalizations (n=7; 17%), and disruptive behavior (n=6; 14%).

Study Characteristics

Data on settings, IOA, procedural fidelity, assessment or analysis type, and whether assessments informed treatment are summarized in Table 1. Most studies were conducted in schools (n=7; 47%), followed by clinics (n=6; 40%), homes (n=2; 13%), and a hospital (n=1; 7%). Most studies (when the article contained two studies, both were counted) reported IOA (n=16; 94%). One study assessed procedural fidelity (n=1; 6%). Nine studies (60%) evaluated a treatment informed by the results of an assessment or experimental analysis, all of which demonstrated the treatment effectively decreased or eliminated challenging behavior.

Precursors

One hundred and five different precursors were identified (i.e., there were 105 different descriptions of, or labels for, precursors) by indirect assessment, direct assessment, precursor analysis (PA), or precursor functional analysis (PFA). The majority of precursors were non-vocal (n=87; 83%), and 18 precursors consisted of vocal responses (e.g., vocalizations, saying “no”, 17%). Five studies subjected hypothesized precursors to an experimental analysis using PFA (33% of all studies). Four of those studies (i.e., excluding Dracobly & Smith, 2012), included an FA of challenging behavior, and the results of the FA and PFA matched for 14 participants (93%). Most PFAs identified an escape function (n=10; 63%), followed by a tangible function (n=5; 32%), an attention function (n=2; 13%) and multiple functions (n=1; 6%). An automatic function was analyzed for nine participants, but none of the analyses identified an automatic function.

Extinction Analyses

A total of 15 participants in nine studies were subjected to an extinction analysis (EA) to identify and characterize a RCH. Major design and display features are summarized by type and study in Table 2. The mean number of challenging topographies targeted in an EA was three (range, 2-4). For 14 participants, the EA was preceded by an FA to identify the reinforcers maintaining challenging behavior. The results of all FAs were differentiated. A single function was identified for 79% of participants (n=11), and multiple functions were identified for 21% of participants (n=3). For most of these participants, a tangible function was identified (n=7; 50%), followed by an attention function (n=6, 43%), or an escape function (n=5; 36). No FA that preceded an EA identified an automatic function.

Seventeen different challenging topographies (or groups of topographies) were identified and assessed in an EA for their ordinal positions in an RCH. Aggression (n=10; 67% of participants), disruption (n=6; 40% of participants), yelling, screaming, or loud vocalizations (n=4; 27%), severe (n=3; 20%), destructive (n=2; 13%), mouthing (n=2; 13%), and self-injurious behavior (n=2; 13%) were the most frequently assessed topographies. All other topographies were each targeted for only one participant. The top four topographies most frequently ranked 1st in an RCH, meaning the most probable response, were disruption (n=4; 27% of participants), followed by lesser or mild severity (n=3; 20%), yelling, screaming, or loud vocalizations (n=2; 13%), and destructive behavior (n=2; 13%). The top four topographies most frequently ranked 2nd in an RCH were yelling (n=2; 13%), severe (n=1; 7%), grabbing (n=1; 7%), and dangerous acts (n=1; 7%). The top five topographies most frequently ranked 3rd in an RCH were disruption (n=2; 13%), mouthing (n=1; 7%), self-injurious behavior (n=1; 7%), flopping to the floor (n=1; 7%), and inappropriate language or gestures (n=1; 7%). The top three topographies most frequently ranked 4th in an RCH were aggression (n=2; 13%), destructive behavior (n=1; 7%), and the threat of aggression (n=1; 7%).

Assessments and Experimental Analyses

Eleven assessments and two experimental analyses were identified, and a list is provided in Table 3. The most frequently used type of assessment was comparative probability analysis (CPA; n=6 studies; 40%), followed by lag-sequential analysis (LSA; n=2 studies; 13% of assessments), latency-based EA (n=2 studies; 13%), EA (n=3 studies; 20%), and brief latency-based EA (n=2 studies; 13%). Indirect precursor assessment (ICA), trial-based structured precursor assessment (TB-SPA), transitional probability analysis (TPA), PA, and severity-based EA (SBEA) were each used once. Six studies used experimental analyses (Multiple-function PFA, n=5; severity-based functional analysis (SBFA), n=1).

DISCUSSION OF METHODS

Indirect Assessments

A wide range of potential precursors of a RCH can be identified utilizing an indirect precursor assessment and subsequently subjected to descriptive assessment (DA) and FA for the purpose of verifying their membership in the target response class of challenging behavior. For example, during interviews of 16 of the participant's teachers, Herscovitch et al. (2009) (a) defined the concept of the precursor, (b) asked interviewees to list potential precursors to a more severe target topography of the participant's challenging behavior, and (c) asked them to rank precursors based on the order in which they are typically observed prior to the target challenging topography. The results of the interviews pinpointed a specific precursor reported to most consistently precede the target topography, which was subsequently verified by CPA and PFA.

Direct assessments

CPA, LSA, TPA, and TB-SPA which may be referred to as methods of descriptive analysis (Bakeman & Gottman, 1986), are primary analyses of conditional or unconditional probabilities of target topographies of behavior based on data collected during direct observation. The purpose of these analyses is to identify potential precursors to challenging behavior (Borrero & Borrero, 2008, study 2), or functionally-equivalent less severe forms of challenging behavior (Shukla-Mehta & Albin, 2003). In contrast, an RLA is a secondary analysis applied to data collected during an FA or systematic treatment evaluation to identify and characterize a RCH by indirectly assessing the temporal relationship among topographies of challenging behavior.

Comparative Probability Analysis

Conditional and unconditional probabilities for one (e.g., Dracolby & Smith, 2012) or multiple (e.g., Fritz et al., 2013) potential precursors can be calculated using data collected during DA (Borrero & Borreo, 2008, study 1; Herscovitch et al., 2009), an EA (Richman et al., 1999), the baseline phase of a treatment evaluation (Dracolby & Smith, 2012), a TB-SPA resembling FA test conditions (Fritz et al., 2013), or actual test conditions of an FA (Shukla-Mehta & Albin, 2003). Typically, conditional and unconditional probabilities are calculated for both precursors and/or less severe response forms, and severe forms of challenging behavior. A CPA suggests responses are precursors when conditional probability values exceed unconditional probability values (Borrero & Borrero, 2008, study 1).

For example, Borrero and Borrero (2008) calculated conditional and unconditional probabilities of potential precursors and challenging behavior using data collected during DA. Conditional probabilities were (a) the probability of a precursor given challenging behavior, and (b) the probability of challenging behavior given a precursor. Specifically, a precursor was recorded as preceding challenging behavior it if occurred within 10 s of an instance of challenging behavior, and challenging behavior was recorded as following a precursor if it occurred within 10 s following an instance of the precursor. For example, a conditional probability of a precursor given challenging behavior would be assigned a value of .8 for a given observation period if the precursor occurred within the preceding 10 s of 4 out of 5 instances of challenging behavior. Unconditional probabilities were (a) the probability of a precursor given an opportunity to respond, and (b) the probability of challenging behavior given the opportunity to respond. Unconditional probabilities were calculated by dividing the number of instances of the behavior (either precursor or challenging behavior) by the number of opportunities to respond. For example, if a response is typically 5 s in duration, and the observation period is 60 s, there are 12 opportunities to respond. If six responses are observed, the unconditional probability is .5. When probabilities are calculated using data from a TB-SPA, the number of trials conducted in the structured assessment can be used as the denominator (Fritz et al., 2013). For example, the conditional probability of a precursor given the target challenging behavior is calculated by dividing the number of trials with the challenging behavior that contained a precursor response, by the total number of trials with challenging behavior. And, the unconditional probability of the precursor is calculated by dividing the number of trials containing the precursor by the total number of trials.

Lag-Sequential Analysis

Calculation of conditional and unconditional probabilities for an LSA have been based on data collected during DA (Borrero & Borrero, 2008, study 1) and the baseline phase of a treatment evaluation (Dracolby & Smith, 2012). A major difference from CPA is that LSA consists of calculating second-by-second probabilities within a larger window of time preceding and following either the precursor or target challenging behavior (e.g., +/- 50 s of the precursor, Borrero & Borrero, 2008, study 1). Data are displayed on a line graph with time (e.g., +/- 50 s) on the abscissa, and the probability of the response (either the precursor or challenging behavior) on the ordinate. When challenging behavior is used as a reference point at the center of the abscissa, if the conditional probabilities of the precursor occurring are relatively higher during the seconds just preceding challenging behavior, the data indicate a precursor. Similarly, when the precursor is used as a reference point at the center of the abscissa, if the conditional probabilities of challenging behavior are relatively higher during the seconds just following the precursor, the data indicate a precursor has been identified.

Transitional Probability Analysis

One study conducted a TPA using data collected during a DA in the classroom (Langdon et al., 2008). Features of TPA that differentiate the method from CPA and LSA is the calculation of not only conditional and unconditional probabilities of suspected precursors and topographies of challenging behavior, but also other assumed non-functionally-related behavior within relatively longer time intervals (e.g., 30 s, Langdon et al., 2008).

Trial-Based Structured Precursor Assessment

A TB-SPA was utilized by Fritz et al. (2013) to demonstrate a method based on direct observation that required minimal occurrences of challenging behavior, because it may be relatively better suited than other methods of descriptive analysis for minimizing challenging behavior during assessment. When conditional and unconditional probabilities are analyzed, a response is identified as a precursor if (a) the response is followed frequently by the occurrence of challenging behavior and (b) the response occurs infrequently or not at all when challenging behavior is not observed (p. 106). First, potential precursors and challenging behavior are identified by indirect assessment. Next, the participant is repeatedly exposed to a series of trials resembling test conditions of an FA in the following order using an AB or ABC design: escape, attention, and tangible (only if indicated by prior assessment). A trial ends when the target topography of challenging behavior is observed and reinforced, or 5 minutes elapses. Trials are separated by at least 30 s following the end of the last response cycle of challenging behavior. The assessment is discontinued following 10 trials with the occurrence of the target topography of challenging behavior, unless it is observed in the first 10 trials, in which case additional FA control condition trials are implemented to balance the duration of time participants did and did not emit the target topography of challenging behavior. Probabilities are calculated using data collected from video recordings of the TB-SPA to identify additional precursors not identified in prior assessment. The results of Fritz et al showed that (a) many more precursors were identified by the TB-SPA than prior indirect assessment, (b) identified precursors were largely functionally-equivalent to the target topography of challenging behavior, and (c) identification of precursors was useful in the development of effective interventions.

Relative Latency Assessment

One study conducted an RLA on data collected during an EA (Richman et al., 1999). The analysis is conducted on tabulated data expressed as mean ranks or the percentage of trials in which a specific topography was emitted first. For mean ranks, a ranking of 1 is assigned to the topography, or topographies emitted first each trial, a ranking of 2 is assigned to the topography emitted 2nd each trial, and a ranking of 3 is assigned to a topography that did not occur or was emitted last each trial. The mean rank for each topography is calculated for each phase. For percentage of trials, the percentage of trials in which each topography was emitted first is calculated for each phase. A RCH is indicated by when a consistently escalating pattern of mean ranks or de-escalating percentage of trials emitted first, is observed consistently across phases in a manner consistent with what would be expected of a RCH.

Structured Consequence-Based Assessments

With the exception of PA which does not follow an FA, structured consequence-based assessments follow a conclusive FA and utilize the reinforcers demonstrated to maintain challenging behavior in manipulations of both antecedents and consequences. A common purpose of these assessments is to characterize functional response class structure by verifying predictions about response-response relations along temporal or severity dimensions of responding by systematically manipulating extinction across topographies.

Extinction Analysis

Extinction is systematically manipulated across topographies to assess topographical covariation within a functional response class of challenging behavior. For examples of representative graphed data, see Figures 2d & 2e. An EA can be used (a) to further assess the range of topographies that define a challenging behavior response class when it is suspected to include more members than were observed during an FA (Magee & Ellis, 2000; Richman et al., 1999), or (b) to demonstrate the resurgence of challenging behavior within an RCH (Lieving et al., 2004). Following a conclusive FA, in the first phase of the EA the reinforcer is applied to the most frequently observed topography in the FA (e.g., Magee & Ellis, 2000) or any topographies (e.g., Lieving et al., 2004) of challenging behavior, to establish a steady baseline. Then, one (e.g., Magee & Ellis, 2000) or multiple (e.g., Richman) topographies are placed on extinction as other topographies continue to produce reinforcement.

In a multiple-baseline across topographies (Magee & Ellis, 2000) or sequential design (e.g., ABCA, ABCD; Lieving et al., 2004), as the first topography or topographies contact extinction, the range of responses that contact extinction are expanded in each subsequent phase to include either (a) the next topography in the hypothesized RCH, or (b) the next most frequently emitted topography. This process continues until (a) all topographies of challenging behavior are extinguished, or (b) all topographies are made eligible for reinforcement once again. A RCH is indicated by across-phase replication of response allocation to a previously low or no frequency topography observed when another previously reinforced topography is extinguished, which may include topographies that are not observed in the preceding FA.

In a multielement or reversal design (Richman et al., 1999), phases in which reinforcement and extinction contingencies are applied to different topographies are repeated over time and topographical covariation is examined. A RCH is indicated when (a) the levels of topographies not observed during the FA consistently increase during phases of the EA in which previously observed topographies are placed on extinction, and (b) topographies observed during the FA continue to occur during phases of the EA in which the previously unobserved topographies are differentially reinforced.

Latency-Based Extinction Analysis

A sequential design (e.g., ABC; DeRosa et al., 2013, or ABCABCD; Lalli et al., 1995) and absolute latencies of each topography per trial are used to evaluate the effects of differentially reinforcing a different topography of the hypothesized RCH across successive phases. For an example of representative graphed data, see Figure 2a. Conditions consist of multiple trials rather than sessions, and a trial is terminated following the first response eligible for reinforcement. A steady state of responding can be used as a criterion for determining when to implement each phase change (Lalli et al., 1995), so session length may vary. A single reinforcement contingency is applied to a different topography in each successive phase of the EA. By targeting the suspected lowest probability topography in the RCH during the first phase, the absolute latency to each other topography in the RCH can be observed. As the contingency is applied to the next lowest probability topography in the RCH in each subsequent phase (i.e., to increasingly more probable topographies), a RCH is indicated by the systematic reduced occurrence of lower probability topographies. In some cases, the absolute latencies of all topographies emitted each trial during the first phase may occur in a highly consistent temporal order thereby revealing the RCH.

Brief Latency-Based Extinction Analysis

An ABCD design constitutes the baseline phase of an ABAB treatment evaluation, and consists of only a few trials (e.g., 4 trials, Pritchard et al., 2011). For an example of representative graphed data, see Figure 2b. The purpose of the assessment is to determine if target topographies are temporally ordered in a manner consistent with a RCH (Mace et al., 2011). Each trial is defined as a 10 (Pritchard et al., 2011) or 15 minute (Mace et al., 2011) session. In trial 1 (i.e., condition A), the reinforcer identified in the preceding FA (Mace et al., 2011) or other assessment methods (Pritchard et al., 2011) is delivered contingent on the first occurrence of the first target topography. In each subsequent trial (e.g., conditions B, C) except for the last (e.g., condition D), reinforcement is scheduled for the next observed topography. In the last trial, all topographies are placed on extinction. The absolute latency to first occurrence of each topography is displayed in a bar graph and examined for evidence of a RCH. To the extent that a within-session pattern of increasing latencies across topographies is replicated across trials, a RCH is identified. The assessment may also be replicated in a return to baseline at a later stage of the subsequent treatment evaluation (Mace et al., 2011).

Precursor Analysis

The purpose of a PA is to identify precursors to more severe topographies of challenging behavior (Langdon et al., 2008). For an hypothetical example of representative graphed data, see Figure 2g. This assessment is similar to (a) a variation of the severity-based EA (Harding et al., 2001) in that precursors are hypothesized less severe members of a response class of challenging behavior, (b) variations of EA in which extinction is differentially applied to different topographies in alternating conditions (e.g., Richman et al., 2004), and (c) PFA, in which precursors are differentially reinforced in the context of an FA (e.g., Dracobly). However, a critical difference is that the PA does not include a control condition and is not followed by functional analysis, and therefore cannot demonstrate functional equivalence of hypothesized precursors and topographies of challenging behavior. The PA can only demonstrate covariation in precursors and topographies of challenging behavior that coincide with the presence and absence of suspected maintaining consequences, which may be considered suggestive of a RCH. Specifically, a RCH is suggested if (a) levels of challenging behavior are consistently low when suspected reinforcers are delivered contingent on precursors, and (b) precursors continue to be emitted in conditions in which suspected reinforcers are delivered contingent on challenging behavior.

Severity-Based Extinction Analysis

A withdrawal design (e.g., ABA, Shukla-Mehta & Albin, 2003) is used to examine covariation among mild and severe topographies of challenging behavior. For an example of representative graphed data, see Figure 2f. During condition A, previously identified maintaining reinforcers are delivered contingent on all topographies of challenging behavior. During condition B, mild topographies are placed on extinction. A RCH is indicated when levels of severe topographies are relatively lower under condition

A relative to condition B, and levels of mild topographies remain elevated during condition B.

Experimental Analyses

A common feature of PFA and severity-based EA with a control condition is the use of FA in the context of assessing response class structure. Experimental analyses have been used to verify functional-equivalence of (a) precursors and challenging topographies of behavior (Borrero & Borrero, 2008, study 2; Fritz et al., 2013; Herscovitch et al., 2009), or (b) more and less severe forms of challenging behavior (Harding et al., 2001), and (c) to demonstrate the function of potential precursors and examine their covariation with challenging topographies of behavior (Dracolby & Smith, 2012).

Precursor Functional Analysis

After identification of potential precursors by indirect (e.g., Herscovitch et al., 2009) or direct assessment (e.g., Borrero & Borrero, 2008, study 1), FA procedures based on Iwata et al. (1982/1994) are employed in a multi-element design to test for multiple functions of precursors (Dracobly et al., 2012), or precursors and topographies of challenging behavior (e.g., Fritz et al., 2013). For examples of representative graphed data, see Figure 2c & 2h. Typically, an FA of challenging behavior is conducted, followed by a separate PFA (Smith & Churchill, 2002; Borrero & Borrero, 2008, study 1; Herscovitch et al., 2009). However, one study conducted the PFA first, based on the rationale that the occurrence of precursors might be more probable in a PFA due to exposure to contingencies during the FA of challenging behavior, and clinical situations in which PFA are conducted would likely not follow an FA of challenging behavior when the purpose of the PFA is to develop a function-based treatment without reinforcing severe topographies during assessment (Fritz et al., 2013). A study by Dracobly and Smith (2012) represents an exception. Rather than conducting both FA and PFA, the authors only conducted a PFA and challenging behavior was graphed separately from the precursor to examine covariation between precursors and topographies of challenging behavior in test conditions. A major limitation of this approach is that without a separate FA of challenging behavior, functional equivalence of challenging behavior topographies and precursors cannot be demonstrated (Dracobly & Smith, 2012).

With the exception of Dracobly and Smith (2012), generally responses are considered precursors if (a) the function identified in the FA of challenging behavior matches the function identified in the PFA, and (b) rates of precursor responses are elevated during test conditions of the FA of challenging behavior, or (c) if rates of challenging behavior are lower during the PFA relative to rates observed in the FA (e.g., Fritz et al., 2013).

Severity-Based Extinction Analysis with Control Condition

The primary purpose of this EA is to evaluate the function of mild and severe topographies of challenging behavior by using extinction to assess the potential hierarchical structure of the response class in the context of an FA (Harding et al., 2001). An FA based on procedures described by Iwata et al. (1982/1994) using a multielement design with embedded reversal is conducted across phases in which contingencies are programmed for all topographies in one phase, and only severe topographies in another phase. Examples of mild topographies have included tantrums and task refusal, and examples of severe topographies have included attempts to engage in self-injury, aggression, or property destruction (Harding et al., 2001). Data are graphed on equal-interval line graphs in two panels, with mild behavior in the top panel and severe behavior in the bottom panel. A RCH is indicated when (a) levels of severe topographies are lower under conditions in which reinforcement is available for mild topographies, and (b) levels of both severe and mild topographies are elevated when reinforcement is contingent on severe topographies.

GENERAL DISCUSSION

The results of the current synthesis demonstrate that behavior analysts have developed multiple methods for characterizing the response class structure of challenging behavior at every stage of FBA including FA, and during treatment. Common features are a focus on the temporal relationship among members of functionally-equivalent topographies of challenging behavior under conditions of reinforcement or extinction, and escalation along one or more dimensions (e.g., severity) under extinction. These common features suggest that each method may be used in one or more capacities to identify and characterize RCH by targeting (a) members of the response class that reliably precede and predict members at other levels of the hierarchy (i.e., precursors), (b) relatively less severe challenging topographies, or (c) by directly targeting severe challenging topographies. The finding that only 15 studies met criteria, and that few of the methods have been replicated, suggests there is a need for additional research focused on replicating existing methods across settings, participants, and skill domains, and developing more methods useful for assessing response class structure at different stages of treatment. Additionally, highly detailed clinical demonstrations of how the methods can be incorporated into treatment development and progress monitoring may help practitioners put the methods into practice.

All of the reviewed studies included participants with intellectual disabilities and/or developmental disorders. The age range of participants (3 – 54 years) suggests the methods are applicable across the lifespan to behaviors with varying lengths of learning histories. Future research could examine the generality of existing procedures by pursuing replication with typically developing individuals. These studies were mostly conducted in schools and clinics, but some were conducted in homes and a hospital setting, suggesting compatibility with a wide range of environments. The compatibility of these methods with home and other community settings could be further investigated.

The believability of the data was assessed by nearly all studies suggesting a high level of methodological rigor with respect to the dependent variable. However, only one study reported the integrity of independent variables, which increases uncertainly about internal validity of this body of work. Future research could reduce uncertainty about internal validity and minimize the probability of false positives or negatives, measurement bias, and treatment drift (Cooper, Heron, & Heward, 2007) by reporting the results of rigorous assessments of procedural fidelity.

The concept of the precursor originated with Smith and Churchill (2002) and gave rise to a variation of FA methodology used to identify functions of challenging behavior without repeatedly reinforcing harmful or high risk topographies. The results of this synthesis indicate that precursors in the reviewed literature have taken the form of both vocal and non-vocal responses, and that precursor topographies can vary widely. For studies that used PFA and an FA of challenging behavior, their results confirmed that precursors and topographies of challenging behavior were members of the same functional response class. PFAs mostly identified responses with escape and tangible functions. The lack of PFA on behavior maintained by attention might be due in part to logistical challenges. Precursors maintained by attention might be relatively difficult to identify using PFA because the subtle nature of some responses may require the experimenter to both carefully observe the participant and withhold attention when non-target responses occur, until the target precursor occurs. No studies in the current review assessed response class structure of automatically maintained behavior such as so-called "self-stimulatory" behavior (e.g., rocking, mouthing, hand flapping) which in some cases may consist of a RCH (Baer, 1982), but the theoretical and clinical implications of doing so could be explored in future research.

For those studies that implemented a treatment following assessment or experimental analysis of response class structure, all studies demonstrated improvements in challenging behavior and/or alternative appropriate topographies. This finding suggests that the methods are useful for developing effective function-based treatments. Theoretical and empirical work suggests the recurrence of challenging behavior, such as spontaneous recovery, reinstatement, renewal, and resurgence following disruptions in treatment are attributable to complex interactions between histories of reinforcement and punishment (e.g., Lattal & Wacker, 2015; St. Peter, 2015). Similarly, complex reinforcement and punishment histories have been implicated in functional response class structure (e.g., Lalli et al., 1995). Therefore, response class structure and recurrence phenomena may be products of common controlling variables and changes to one phenomenon may alter the other. When an extensive account of the learning history that gave rise to a given class of challenging behavior is inaccessible during treatment development, as it is in most cases, characterization of response class structure (i.e., relative probabilities or response strength, the range of variations within the response class) produced by that history may provide treatment-relevant information beyond that which may be gathered in a standard functional behavior assessment. Future avenues of research could examine how integrating assessment and experimental analysis of response class structure across treatment development and monitoring might be used to alter the response class structure of challenging behavior for the purpose of minimizing or preventing recurrence.

Although response class structure may vary with punishment contingencies (Baer, 1982; Lalli et al., 1995; Sprague & Horner, 1992), no studies in the current synthesis manipulated punishing contingencies to assess response class structure. In applications of FCT to replace challenging behavior with appropriate response forms, it may sometimes be necessary to include punishment contingencies to reduce challenging behavior to clinically acceptable levels (Hagopian et al., 1998). Therefore, future research examining the effects of punishment on response class structure may not only make important theoretical contributions in terms of our understanding of response class structure, but also clinical contributions by expanding on assessments and experimental analyses of response class structure and clarifying their potential clinical utility.

The RCH was originally conceptualized as a functional response class consisting of a variety of response topographies which occur with a relatively predictable temporal order as environmental contingencies change (Baer, 1982). And the results of this synthesis suggest clinical applications of the RCH concept have focused exclusively on topography (e.g., hitting, hair pulling, pinching, vocalization) in the assessment of response class structure. However, recent studies have expanded the concept of the RCH to include topographically invariant selection-based responses (e.g., button presses or card-touch responses in translational work) that vary along a given dimension such as effort (Shabani et al., 2009) or reinforcer quality (Beavers et al., 2014). Further discussion of these issues is beyond the scope of the current synthesis and would benefit from additional conceptual work. Exclusion of studies which conceptualized RCH in terms of selection-based rather than topography-based responses may be considered a limitation of the current study and different conclusions may have been reached had the inclusion criteria been less restrictive.

IMPLICATIONS FOR PRACTICE

Defining features, and potential benefits and limitations of each type of assessment and experimental analysis are listed in Table 4. Whether treatment effects, maintenance, or generalization are more robust when treatment progression is based on data from assessments of response class structure could be investigated in future research. However, practitioners may still find some tentative guidelines, pending additional research, for selecting methods of characterizing response class structure useful within the context of a "best available evidence" approach to evidence-based practice which includes consideration of client values, context, and clinical expertise (Slocum et al., 2014). The results of this synthesis may also help practitioners determine the best fit between the methods and a given clinical problem by providing estimates of internal validity, efficiency, benefits, and limitations.

Indirect and direct assessments may be considered to range from low (IPA), to medium (CPA, LSA, TPA), to high (RLA, TB-SPA) internal validity based on the extent to which the practitioner utilizes direct observation in the relevant context and manipulates consequences contingent on responding. If practitioners use IPA, they likely increase the risk of informants failing to identify functionally-equivalent responses

(Dracobly & Smith, 2012; Fritz et al., 2013; Herscovitch et al., 2009) and therefore might consider following up with a TB-SPA (Fritz et al., 2013).

Practitioners who wish to minimize time and resources spent on assessment and treatment development might consider selecting the most efficient methods. The full range of methods for assessing response class structure may be considered to span along a continuum of efficiency from low (CPA, EA, LSA, PA, PFA, RLA, SBEA, SBEA with control condition, TPA) to medium (Latency-based EA, TB-SPA), to high (IPA, Brief latency-based EA).

Each method of characterizing response class structure has potential benefits which may also be considered based on a wide range of variables associated with the characteristics of the participant's challenging behavior and the context in which it is being maintained. If ease of use and efficiency are high priorities, practitioners may consider using IPA followed by a latency-based EA or brief latency-based EA. If programmed reinforcement is to be avoided so that naturally occurring contingencies produced by challenging behavior can be observed and noted for further assessment, IPA, CPA, LSA, or TPA might be utilized. If it is preferred to characterize a range of response class members without placing responses on extinction, but without sacrificing internal validity, practitioners may consider the use of RLA during an experimental analysis or treatment evaluation. If a practitioner aims to identify a wide range of topographies that define a response class, they may consider using a brief-latency based EA, EA, latency-based EA, RLA, SBEA, SBEA with control condition, or TB-SPA. If a goal is to minimize the occurrence and programmed reinforcement of challenging behavior during assessment, the practitioner could use TB-SPA or a brief latency-based EA. If the practitioner wished to proceed with assessment of response class structure but the current data do not suggest an RCH, they may use a brief latency-based EA, EA, or latency-based EA. If demonstration of the functional equivalence of multiple responses is desired, the practitioner could use PFA or SBEA with a control condition.

Practitioners may also wish to avoid methods with certain limitations. Use of IPA alone may run a relatively higher risk of false positives or negatives compared to other methods. CPA, LSA, TA, PA, and SBEA can reveal correlations helpful for forming hypotheses about response class structure, but cannot demonstrate functional relations. Therefore, practitioners may consider following up with PFA or SBEA with a control condition. However, PFA may risk inadvertently adding new problematic topographies (i.e., the supposed precursor responses) to the response class if hypotheses about precursors were incorrect. A potential limitation of most methods (RLA, TB-SPA, latency-based EA, EA, brief latency-based EA, PA, SBEA) is that data collection on multiple dependent variables may require video recording sessions, which requires more time and staff resources despite some of the actual procedures being relatively efficient (brief latency-based EA, TB-SPA). If practitioners struggle with implementing FA test conditions, they should seek out additional training or seek guidance from another appropriate practitioner before conducting TB-SPA, PFA, or SBEA with a control condition. When reinforcing severe topographies is unacceptable, practitioners should consider avoiding TB-SPA, latency-based EA, EA, brief latency-based EA, PA, SBEA, and PFA.

Table 1

Summary of Study Characteristics

Study	Setting	IOA	Fidelity	Type of Assessment or Experimental Analysis	Informed Treatment
Borrero & Borrero, 2008	School	S1: Yes S2: Yes	S1: NA S2: No	Multi-function PFA preceded by CPA, & LSA	Not evaluated
DeRosa et al., 2013	Clinic	Yes	No	Single-function latency-based EA preceded by FA	Yes, effective
Dracobly & Smith, 2012	Clinic	S1: Yes S2: Yes	S1: No S2: No	Multi-function PFA preceded by CPA, & LSA	Yes, effective
Fritz et al., 2013	School & Clinic	S1: No S2: Yes	S1: No S2: No	Multi-function PFA preceded by TB-SPA with CPA	Yes, effective
Harding et al., 2001	Home	Yes	No	SBFA	Not evaluated
Herscovitch et al., 2009	School	Yes	No	Multi-function PFA preceded by IPA & CPA	Not evaluated
Lalli et al., 1995	Hospital	Yes	Yes	Single-function latency-based EA preceded by FA	Yes, effective
Langdon et al., 2008	School	Yes	No	Single-function PA preceded by TPA	Yes, effective
Lieving et al.., 2004	Clinic	Yes	No	Single-function EA preceded by FA	Not evaluated
Mace et al., 2011	School	Yes	No	Brief single-function latency-based EA preceded by FA	Yes, effective
Magee & Ellis, 2000	School	Yes	No	Single-function EA preceded by FA	Embedded in assessment

Table 1

Continued.

Pritchard et al., 2011	School	Yes	No	Brief single-function latency-based EA	Yes, effective
Richman et al., 1999	Clinic	Yes	No	Single-function EA with CPA and RLA	Not evaluated
Shukla-Mehta &Albin, 2003	Home	Yes	No	SBEA preceded by CPA and FA.	Yes, effective
Smith & Churchill, 2002	Clinic	Yes	No	Multiple-Function PFA	Not evaluated

Note. CPA = comparative probability analysis, EA = extinction analysis, FA = functional analysis, IPA = indirect precursor assessment, LAS = lag-sequential analysis, PA = precursor analysis, PFA = precursor functional analysis, RLA = relative latency assessment, SBEA = severity-based extinction analysis, SBFA = severity-based functional analysis TPA = transitional probability analysis.

Table 2

Major Design and Display Features of Extinction Analyses

Study	Part	Design	Sessions	Dependent Measures	Data Display
			Latency-Based Extinction Analysis		
DeRosa et al., 2013	1	ABC	Unable to determine	Absolute latency to first occurrence of each challenging topography	Bar graph
	2	AB	Single-trial	Absolute latency to first occurrence of each challenging topography	Bar graph
Lalli et al., 1995	1	ABCABCD	Multiple-trial	Absolute latency to first occurrence of each challenging topography	Bar graph
			Brief Latency-Based Extinction Analysis		
Mace et al., 2011	1	ABCD	Single-trial, 15 minutes	Absolute latency to first occurrence of each challenging topography	Bar graph
Pritchard et al., 2011	1	ABCD	Single-trial, 10 minutes	Absolute latency to first occurrence of each topography of challenging behavior	Bar graph
			Severity-Based Extinction Analysis		
Shukla-Mehta & Albin, 2003	1	ABA	Unable to determine	Rate in minutes of the target topography of challenging behavior (primary), absolute response latencies (secondary)	Equal-interval line graph primary display), Bar graph (secondary display)
			Severity-Based Functional Analysis		
Harding et al., 2001	1	Multi-element with reversal	5 Minutes	1) Percentage of intervals with mild or severe challenging behavior 2) Absolute latency to first occurrence of mild and severe challenging behavior	Equal-interval line graph

Table 2

Continued

Extinction Analysis					
Study	Part.	Design	Sessions	Dependent Measures	Data Display
Richman et al., 1999	1	Multi-element with pre-analysis baseline	5 minutes	Percentage of intervals with each topography of challenging behavior (primary), conditional probability analysis (secondary), and relative response latencies (tertiary)	Equal-interval line graph
	2 & 3	Reversal with pre-analysis baseline	5 minutes	Percentage of intervals with each topography of challenging behavior (primary), conditional probability analysis (secondary), and relative response latencies (tertiary)	Equal-interval line graph
Lieving et al., 2004	1	ABCA	10 minutes	Rate in minutes of the target topography of challenging behavior	Equal-interval line graph (rate, primary display; cumulative record, secondary display)
	2	ABCD	10 minutes	Rate in minutes of the target topography of challenging behavior	Equal-interval line graph (rate, primary display; cumulative record, secondary display)
Magee et al., 2000	1	Multiple-baseline across behaviors	10 minutes	Percentage of intervals for each target topography of challenging behavior	Equal-interval line graph

Table 3

Methods of Assessment and Experimental Analysis for Characterizing the Response Class Structure of Challenging Behavior

	Assessments
Indirect	
	Indirect precursor assessment (Herscovitch et al., 2009)
Direct	
	Comparative probability analysis (e.g., Borrero & Borrero, 2008)
	Lag-sequential analysis (e.g., Dracobly & Smith, 2012)
	Transitional probability analysis (Langdon et al., 2008)
	Trial-based structured precursor assessment (Fritz et al., 2013)
	Relative latency assessment (Richman et al., 1999)
Structured Consequence-Based	
	Latency-based extinction analysis (e.g., Lalli et al., 1995)
	Extinction analysis (e.g., Magee & Ellis, 2000)
	Brief latency-based extinction analysis (e.g., Mace et al., 2011)
	Precursor analysis (Langdon et al., 2008)
	Severity-based extinction analysis (Shukla-Mehta & Albin, 2003)
	Experimental Analyses
Precursor-Based	
	Multiple-function precursor functional analysis (e.g., Smith & Churchill, 2002)
	Severity-based functional analysis with control condition (Harding et al., 2001)

Note. Examples are in parentheses.

Table 4

Defining Features, Potential Benefits, and Potential Limitations of Assessment and Experimental Analysis Variations

	Critical Features	Potential Benefits	Potential Limitations
		Indirect Assessments	
Indirect precursor assessment (e.g., Herscovitch et al., 2009)	• Survey-based with rankings	• Ease of use and efficiency (Hersovitch et al., 2009) • Does not require programming for reinforcement of the behavior during assessment	• Informants may not correctly identify precursors, may rank them incorrectly (Herscovitch et al., 2009; Fritz et al., 2013), or may bias reports towards recent or dramatic events (Dracobly & Smith, 2012) • Sufficient multiple informants may not be available for interview
		Direct Assessments	
Comparative probability analysis	• Calculation of probabilities seconds before and/or after an instance of the precursor and challenging behavior (e.g., 10 s, Borrero & Borrero, 2008)	• Comparing probabilities may lead to fewer Type 1 errors associated with less formal DA or IA methods by identifying more precise temporal relations between precursors and challenging behavior (Dracobly & Smith, 2012), and making more precise distinctions between response-response correlations • Does not require programming for reinforcement of the behavior during assessment	• Inferences about precursors or less severe topographies are based on correlations, and may require validation by functional analysis (Borrero & Borrero, 2008). • May be too time consuming or complex for practitioners without extensive training or with limited service hours
Lag-sequential analysis	• Calculation of second-by-second probabilities seconds before and after the precursor and challenging behavior (e.g., +/1 50 s, Borrero & Borrero, 2008)	• Same as CPA	• Same as CPA

Table 4

Continued

	Direct Assessments		
	Critical Features	**Potential Benefits**	**Potential Limitations**
Transitional probability analysis	• Calculation of probabilities of precursors, challenging behavior, and other behavior (e.g., 30 s, Langdon et al., 2008)	• Same as CPA	• Same as CPA
Relative latency assessment	• Occurrence rankings used as measure of relative latency	• Does not require the use of extinction conditions • Use to identify and characterize temporal relations after or during an ongoing FA or treatment evaluation • May be used to identify multiple topographies that define a RCH	• An indirect measure of relative latency. • May need to video record sessions to obtain accurate measures, and therefore may require more time and staff resources than other methods
Trial-based structured precursor assessment	• Manipulation of antecedents and consequences in a manner analogous to FA test conditions	• May be relatively better suited than other methods for minimizing the occurrence of challenging behavior during assessment (Fritz el al., 2013) • May identify precursors that are significantly underreported or reported inaccurately by informants (Fritz el al., 2013) • Data collection may be completed in less time than methods that rely only on observation, especially for low rate behavior • May be used to identify a relatively broader range of RCH members when the lowest probability member is targeted in the assessment	• Requires prior training in the use of FA test conditions • May need to video record sessions to obtain accurate measures, and therefore may require more time and staff resources than other methods • May yield some false positives for some individuals (Fritz el al., 2013) • Reinforcing severe topographies may be clinically contraindicated in some cases

Table 4

Continued

Structured Consequence-Based Assessments			
	Critical Features	**Potential Benefits**	**Potential Limitations**
Latency-based extinction analysis	• Sequential application of extinction to different topographies across conditions and absolute repeated measures of latency	• May be used to identify multiple topographies that define a RCH • May identify appropriate topographies to reinforce in treatment, thereby reducing treatment time (DeRosa et al., 2013) • May be completed within a few brief sessions.	• Internal validity may be vulnerable to sequence effects (Lalli et al., 1995) • Reinforcing severe topographies may be clinically contraindicated in some cases • May need to video record sessions to obtain accurate measures, which may require more time and staff resources than other methods
Extinction analysis	• Sequential application of extinction to different topographies across conditions using within-session non-latency-based repeated measures	• May serve as treatment when it is clinically prudent to eliminate the behavior rather than teach an alternative topography to request the reinforcer • Does not require a prior hypothesis about the hierarchical organization of the response class. • May be combined with a secondary analysis to examine within-session response patterns for resurgence • May be used to identify multiple topographies that define a RCH	• When used as treatment, no new skills are learned • May need to video record sessions to obtain accurate measures, which may require more time and staff resources than other methods • Reinforcing severe topographies may be clinically contraindicated in some cases

Table 4.

Continued.

Brief latency-based extinction analysis	• Sequential application of extinction across a brief series of trials with absolute latency as the dependent measure (e.g., 4 trials, Pritchard et al., 2011)	• May shorten the time to begin treatment by serving as baseline for treatment (Mace et al., 2011) • Very few instances of challenging behavior are reinforced • Does not require a prior hypothesis about the hierarchical organization of the response class. • May be used to identify a full range of topographies that define a RCH	• May need to video record sessions to obtain accurate measures, which may require more time and staff resources than other methods • Reinforcing severe topographies may be clinically contraindicated in some cases
Precursor analysis and severity-based extinction analysis	• Putative extinction contingency differentially applied to precursors or low severity and challenging topographies across phases	• Can identify targets for treatment to prevent escalation to challenging topographies of behavior • Compared to PFA or FA, fewer conditions are required and may require fewer sessions • May be used to identify multiple topographies that define a RCH	• Cannot demonstrate functions of precursors (or less severe topographies) or challenging topographies of behavior • May need to video record sessions to obtain accurate measures, which may require more time and staff resources than other methods • Reinforcing severe topographies may be clinically contraindicated in some cases

Table 4

Continued

	Critical Features	Potential Benefits	Potential Limitations
		Experimental Analyses	
Precursor functional analysis	• Use of FA to identify the function of precursors	• Can identify functions of precursors with high internal validity while minimizing risk to client and practitioner (e.g., Dracobly & Smith, 2012) • Can demonstrate functional equivalence when combined with an FA of challenging topographies (e.g., Borrero & Borrero, 2008)	• Requires prior training in the use of FA test conditions • Reinforcing severe topographies may be clinically contraindicated in some cases • Some reinforced precursors may compete with others, resulting in false negative results (Fritz et al., 2013) • Unless combined with an FA of challenging topographies, cannot demonstrate functional equivalence of precursors • Arranging contingencies for responses preceding challenging topographies may risk adding new responses to the response class rather than merely identify existing response class members.
Severity-based functional analysis	• Extinction differentially applied to challenging topographies of different severities across phases of an FA (e.g., Harding et al., 2001)	• Can identify targets for treatment to prevent escalation to challenging topographies of behavior • Can identify functions and demonstrate functional equivalence of multiple topographies • May be adapted to identify multiple topographies that define a response class.	• May need to video record sessions to obtain accurate measures, and therefore may require more time and staff resources than other methods • Reinforcing severe topographies may be clinically contraindicated in some cases

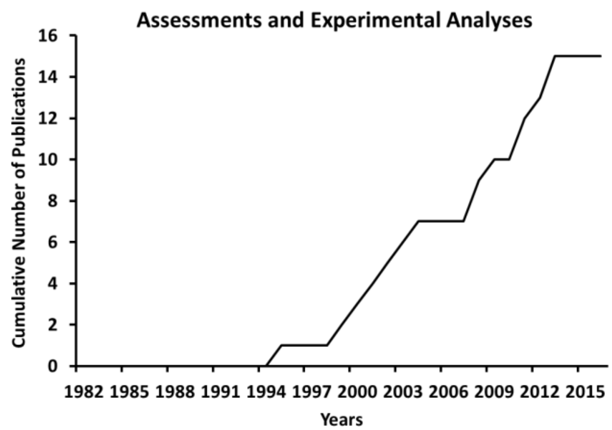

Figure 1. Cumulative number of publications utilizing assessments or experimental analyses related to identification and characterization of RCH structure for 3-year periods between 1982 (Baer's description of response class hierarchy) and April, 2016.

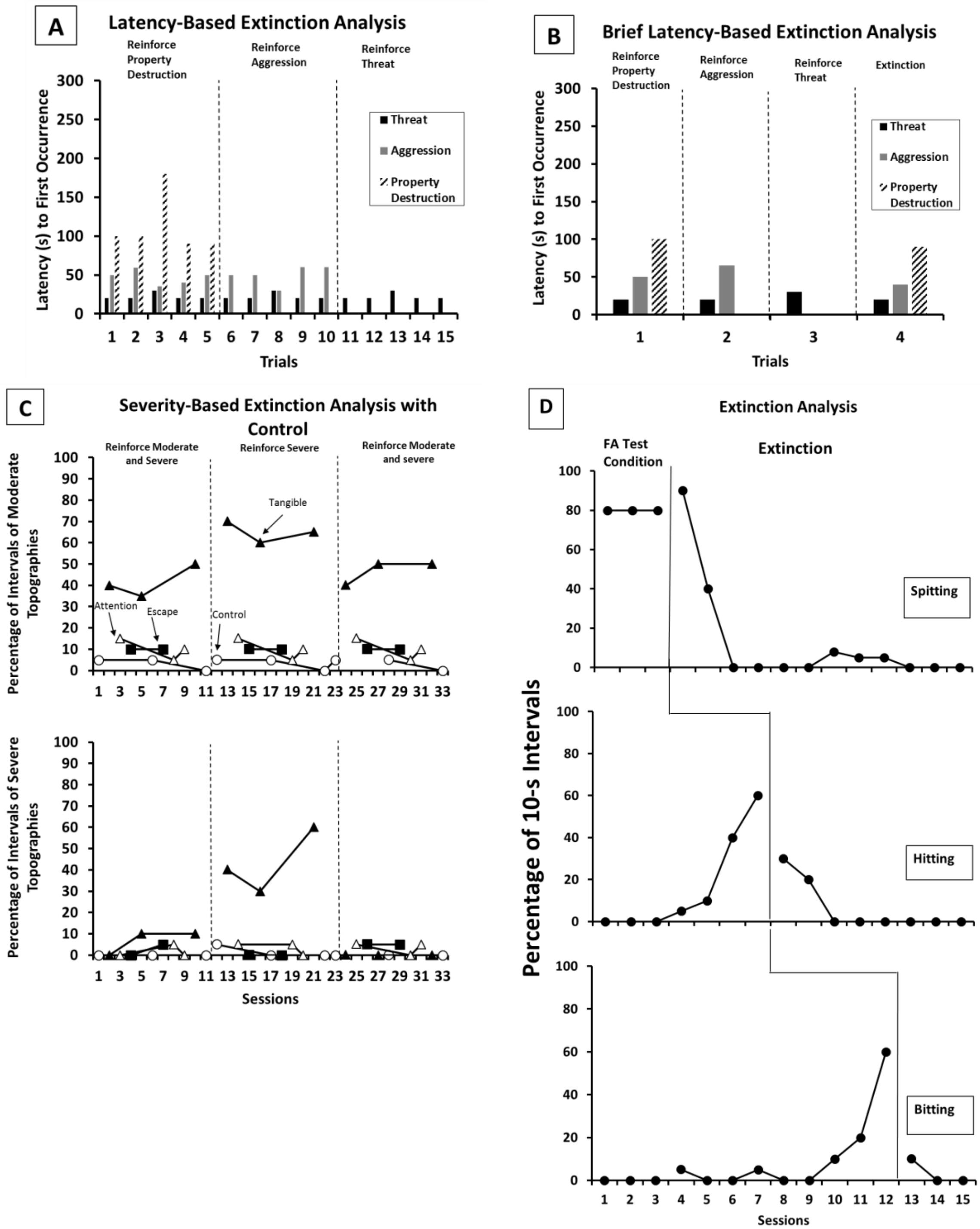

Figure 2. Design variations of structured consequence-based assessments and experimental analyses with hypothetical data.

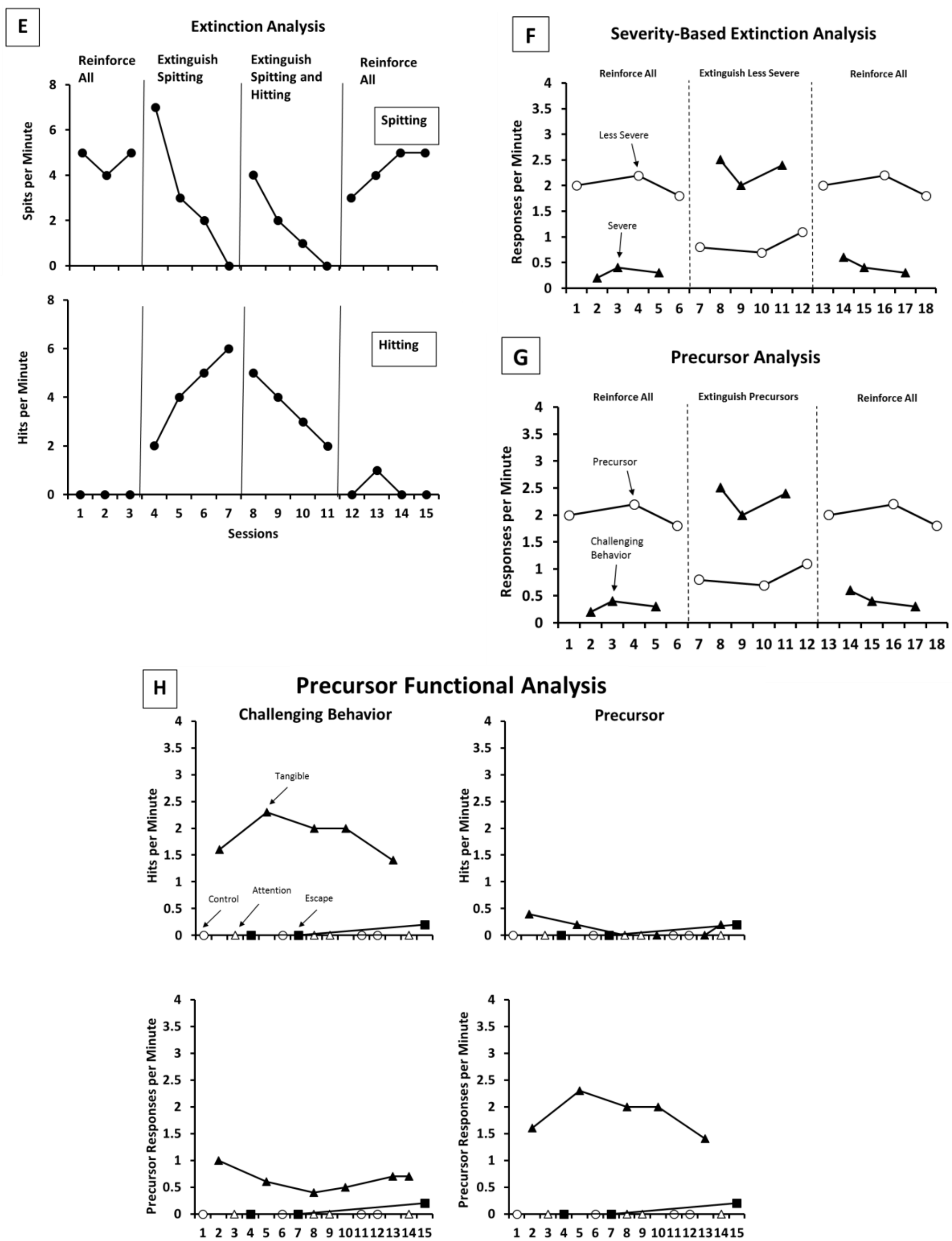

Figure 2. Continued.

Chapter 3: Method

The methods for two experiments are described, including (a) participants, settings, and materials, (b) dependent variables, (c) measurement, (d) assessment of inter-observer agreement (IOA), (e) experimental designs, (f) independent variables, and (g) assessments of procedural fidelity.

EXPERIMENT 1

PARTICIPANT, SETTING, AND MATERIALS

Zahid was a 5-year-old boy of Pakistani descent with a vocal verbal repertoire, and no secondary diagnoses. All sessions were conducted in a 10 x 10 room in Zahid's ABA clinic where he received 1:1 and small group instruction in multiple skill domains including verbal behavior and play skills from Board Certified Behavior Analysts (BCBA) and Speech and Language Pathologists. Sessions were conducted by Zahid's therapist with coaching from the experimenter, with the exception of the multielement FA and duplic assessment which were conducted by the experimenter. Zahid was not receiving a special diet or psychotropic medication. Materials included toys identified using empirical stimulus preference assessments. No instructions were given to clinic staff to withhold access to the toys outside of sessions.

DEPENDENT VARIABLES AND MEASUREMENT

Topographical mand variability and challenging behavior were the primary dependent variables in the treatment evaluation. Challenging behavior was also measured during the FAs. Echoics were measured during the duplic assessment.

Response Definitions

When a response consisted of a complete sentence with three or more words, which differed from the last sentence spoken independently within the session, it was considered an instance of independent variant manding if the following criteria were met. First, no words could be common to both sentences, Second, the sentence needed to consist of English words. Third, the sentence needed to appear to the experimenter relevant to the reinforcer. When a response had the latter two features but did not differ from the last sentence spoken independently within the session, the response was considered an instance of *independent invariant manding*. For example, “let me play” would be variant if it followed “will you share”, but invariant if it followed “I’m still playing”. An instance of variant manding immediately following an echoic prompt was considered an instance of *prompted variant manding*. *Challenging behavior* was defined as spitting, scratching, touching the therapist with hands or feet, pushing, mouthing, hitting, biting, or putting an arm around the therapist’s shoulders or neck, pulling therapist’s clothes, pushing, kicking or tipping furniture over, or hitting the toys in the therapist’s hands. Non-examples were dropping toys over the room partition and touching the therapist when Zahid’s body was turned away from the experimenter. Each instance was counted when physical contact discontinued (e.g., hand removed) or discrete responses (e.g., hitting furniture) were separated by 2 s. Instances of manding and challenging behavior were counted and converted to a rate in minutes by dividing the count by the total duration of the session, including the full duration of sessions that were extended as described in the procedures. Instances of challenging behavior that occurred during access to reinforcement, which were very few, were not counted. The experimenter collected data from video recorded sessions.

INTEROBSERVER AGREEMENT

A trained observer independently viewed videos and coded data during 33% of sessions randomly selected across all phases of the treatment evaluation to assess interobserver agreement (IOA) for rates of challenging behavior, and manding. IOA for manding and challenging behavior were calculated using the *exact count-per-interval* method. Each recording period (i.e., a session) was divided into 10-s intervals. The number of intervals in which both observers recorded the same number of responses was divided by the total number of intervals and the quotient was converted to a percentage. Session IOAs were summed and converted into a mean IOA. Mean IOA was 96% (range, 88 - 100%) for challenging behavior, 98% (range, 88 - 100% for independent variant manding, 98% (range, 81 – 100%) for independent invariant manding, and 99% (range, 94 – 100%) for prompted variant manding.

EXPERIMENTAL DESIGN AND INDEPENDENT VARIABLES

Phase 1: Functional Behavior Assessment

The purpose of the FBA was to generate hypotheses about the function(s) of challenging behavior which could be tested experimentally using FA. The function of challenging behavior was assessed using common indirect and direct assessment methods including semi-structured interviews or questionnaires (indirect), observation (direct) of the behavior in the context in which it was reported by caregivers to occur (i.e., descriptive assessment), and observation of occurrences and non-occurrences of the behavior in the presence and absence of specific antecedent manipulations (i.e., structured assessment or "trigger analysis"; Cipani & Schock, 2011). The results of the FBA suggested that challenging behavior was socially-mediated, and likely multiply maintained.

Phase 2: Functional Analysis

A multielement functional analysis without a tangible condition (Iwata et al., 1982/1994) conducted by the experimenter failed to produce differentiated data. Next, a pairwise FA (Iwata, Duncan, Zarcone, Lerman, & Shore, 1994) was conducted over three visits to test the hypothesis that challenging behavior was maintained by socially-mediated positive reinforcement in the form of access to tangibles. Sessions were 5 min, test and control conditions contained preferred toys, and the order of test and control conditions was randomized. With the exception of one session in which the experimenter demonstrated the procedures for the therapist during some trials, Zahid's therapist ran all sessions with coaching from the experimenter. A free operant stimulus preference assessment (FO-SPA; Roane, Vollmer, Ringdahl, & Marcus, 1998) was conducted to identify preferred toys before the first session on days one and two of the FA.

When the control condition was initiated, the experimenter told Zahid, “It’s play time” and provided him with free access to the same toys used in the test condition. The experimenter provided attention on a fixed-time 10 s schedule, did not present demands, and ignored challenging behavior. Prior to the test condition, the experimenter provided Zahid with 1 min of free access to toys. Throughout the session, the therapist removed access to the toys using errorless physical prompts and waited for challenging behavior to occur. Errorless physical prompts were used because merely beginning to remove access to toys reliably evoked relinquishing problems consisting of throwing and property destruction. Contingent access to toys was provided for 30 s following every instance of challenging behavior. The therapist did not provide attention or deliver demands. Starting with session six, the therapist also said “give me toys” when initiating all subsequent trials in an attempt to minimize relinquishing issues.

Phase 3: Duplic Assessment

Initially, the treatment evaluation was planned to begin with FCT + Lag 1 + TD. During the first two sessions (procedures were identical to the description of this condition below), Zahid failed to consistently imitate echoic prompts for target vocal mand topographies (“will you share”, “I’m still playing”, and “more time please”). Afterward, those sessions were treated as pre-experimental probes, the experimental design was revised, and a duplic assessment was designed and implemented prior to the onset of the first FR 1 session of the current treatment evaluation.

The purpose of the duplic assessment was to identify target vocal mand topographies Zahid would imitate in response to echoic prompts, but without engaging in challenging behavior. Procedures were designed to minimize the likelihood that target mand topographies would come under the control of the EO relevant to challenging behavior prior to the treatment evaluation. A duplic is a verbal operant with formal similarity and point-to-point correspondence to its controlling verbal antecedent stimulus, and maintained by generalized conditioned reinforcement (Michael, 1982). Types of duplics are echoics and copying signs.

Zahid was seated at a table with the experimenter. Prior to the assessment, five different target vocal mand topographies ("will you share?"; "not yet (therapist name)";, "give me toys"; "let me play"; and "more time please") were selected because they were likely to be recognized and reinforced by caregivers and because they required approximately the same amount of response effort. Three trials were conducted for each topography and target topographies were randomly rotated across all trials. A topography met criteria for inclusion in the treatment evaluation if Zahid responded correctly on all three trials for that mand topography. A trial began when the experimenter said "copy me", "say what I say", or other verbal prompt previously determined to be effective, and ended when the experimenter praised (e.g., "Awesome, you said it!") a correct response that occurred within 5 s of the echoic prompt, or 5 s passed without a correct response. The echoic prompt on a trial was repeated once if Zahid said "huh?" or an equivalent, indicating he may not have clearly heard the prompt. Intertrial intervals were 2-3 s. Praise was the only programmed consequence for correct responses. No toys were visible or accessible at the table. The assessment was discontinued when three target vocal mand topographies met criteria. The assessment was completed in one session in under 3 min.

Other forms of compliance such as sitting in the chair were praised. Target vocal mand topographies that met criteria and were to be prompted in the treatment evaluation were “will you share?” “not yet (therapist name)” and “let me play”.

Phase 4: Treatment Evaluation

General Procedures

All sessions were 5 min. A FO-SPA was conducted to identify preferred toys before the first session of each day. Between sessions, if Zahid asked for a toy not identified in the FO-SPA it was included in the subsequent session. During phases in which a contingency for variant vocal manding was programmed, novel or untrained correct sentences (even if grammatically incorrect) were eligible for reinforcement, not just the target vocal mand topographies selected in the duplic assessment. For example, if Zahid said “say not yet (therapist name)”, “say” was not part of the “not yet (therapist name)” target topography identified in the duplic assessment, although this variation was reinforced if all of the words differed from the immediately preceding sentence spoken independently within the session. If challenging behavior or manding had not occurred early into the previous programmed EO of a session and the 5-min session duration elapsed, the session was extended until an instance of manding or challenging behavior (depending on the condition) occurred (the longest session in the treatment evaluation was 7 min 52 s).

FR 1

Prior to the first session of the day in this condition, Zahid was given free access to preferred toys for 1 min. Each trial started with the therapist saying “my turn” and removing access (i.e., the presentation of the EO) to the reinforcer (i.e, toys) using errorless response prompting (to minimize relinquishing problems), and ended when the therapist silently delivered 30 s access to the reinforcer contingent on an instance of challenging behavior. The experimenter did not provide attention during reinforcement intervals or while tangibles were withheld. Elopement from the area was blocked by the therapist and experimenter.

FCT + Lag 1 + TD

This condition was similar to FR 1 with some exceptions. Challenging behavior was placed on extinction. Each instance of independent or prompted topographically variant manding was reinforced. Prompts for variant manding were delivered using a progressive TD (Silbaugh et al., submitted).

The procedures for the first session differed slightly from all other sessions in this condition. Specifically, beginning with the first trial, an echoic prompt to emit a variant vocal mand topography was delivered errorlessly (i.e., paired simultaneously with the removal of toys and therapist statement “my turn”). Each target vocal mand topography was prompted twice, randomly rotated, across six consecutive trials. On the 7th trial, after six consecutive prompted variant responses, the first TD in a progressive TD procedure was introduced.

Zahid was given 2 s (i.e., TD 2-s) to emit a variant vocal mand topography. Zahid could emit multiple responses during the TD, and every response was recorded. If no independent variant vocal mand topography occurred, the therapist delivered an echoic prompt for a quasi-randomly selected target variant vocal mand topography identified in the duplic assessment, at 2 s intervals until Zahid imitated the prompt. That is, echoic prompts were not contingent on invariant vocal mand topographies, but the passage of the full duration of the TD without an independent variant vocal mand topography. After six consecutive trials with no independent variant vocal mand topographies, the therapist increased the TD by 2 s on the seventh trial.

The TD was programmed to continue across sessions until an increase in independent variant vocal manding was observed or the experimenter changed phases. If the therapist ran out of time at the end of a session to increase the TD, she did so on the first trial of the subsequent session. If no independent variant vocal mand topographies were emitted for consecutive trials within a session, but for less than six trials when the session ended, the six-consecutive-trial requirement was reset at the start of the next session. The second instance of this condition implemented in the latter half of the treatment evaluation began with TD 2-s on trial one.

FCT + Lag 1 + LTM

The purpose of this condition was to assess the effects of an alternative prompt fading procedure on rates of challenging behavior and variant manding. This condition was similar to FCT + Lag + TD, with some exceptions. Instead of the TD procedure, the therapist delivered increasingly complete echoic prompts within each trail to evoke variant vocal mand topographies. Each trial, within 1 s of the EO, the therapist immediately delivered an echoic prompt for the first word of the target sentence (e.g., "will"), followed by modeling the first two words of the target sentence (e.g., "will you"), followed by modeling the full target sentence (e.g., "will you share"), with prompts separated by 2 s inter-prompt intervals which allowed for Zahid to say the full target sentence. The reinforcer was delivered for independent or prompted variant mand topographies only if the topography consisted of a full sentence (e.g., “let me play”).

FCT + Lag 0

The purpose of this condition was to assess the effects of FCT without a requirement to vary, on rates of challenging behavior and manding. Sessions were similar to the FR 1 condition, except that challenging behavior was placed on extinction and every independent instance of manding was reinforced, regardless of variance.

FCT + Lag 1

The purpose of this condition was to assess the effects of FCT + Lag 1 without prompts on rates of challenging behavior and variant manding. The condition was similar to FCT + FR 1 except that the reinforcer was delivered contingent on each instance of independent variant manding.

No-Prompt Probe

The purpose of this condition was to use extended periods of extinction to evoke independent instances of variant vocal manding by omitting all prompts during a single session. This condition was identical to FCT + Lag 1, except that had independent variant manding not increased relative to the prior session, the subsequent session would have consisted of a return to a prior phase such as FCT + Lag 1 + TD.

EXPERIMENT 2

PARTICIPANTS, SETTINGS, AND MATERIALS

Three English speaking boys ages 4- and 5-years-old recruited from local service providers served as participants in the current study. They were included because they (a) had a diagnosis of autism spectrum disorder, and demonstrated (b) challenging behavior warranting intervention as determined by functional behavior assessment (FBA), (c) generalized echoic and/or non-vocal imitation repertoires, (d) vocal (i.e., spoken words) or gestural (e.g., pointing or signs) manding repertoires, (e) one or more socially-mediated functions of challenging behavior as indicated by functional analysis (FA), and (f) at least one appropriate mand topography (e.g., point, vocalization, sign) during a pre-treatment FBA (i.e., direct observation, FA, or extinction analysis).

William was a 5-year-old boy of Caucasian and Hispanic descent with a minimally vocal verbal repertoire consisting also of signs and selection-based speaker responses (e.g., card exchange or tablet-based augmentative alternative communication systems). He attended a preschool program for children with disabilities twenty hours per week, and received in-home ABA eight hours per week. William was not receiving a special diet or psychotropic medication. Materials included toys identified for inclusion in a preference assessment, and an iPad ® used during the tangible condition of a functional analysis. No materials were used in the treatment evaluation. All sessions were conducted by the experimenter in William's living room. His mother video recorded the sessions.

Chris was a 4-year-old Caucasian boy with a vocal verbal repertoire. He had received ABA-based early childhood intervention from the first author before age three, but was not receiving ABA at the time of the study. He attended a preschool program for children with disabilities five days per week. Chris was not receiving a special diet or psychotropic medication. All sessions were conducted by the experimenter in Chris's living room, sitting on a couch. The living room was open to the kitchen and dining room, and included standard furniture. No other people were present. His father video recorded the sessions and did not interact with Chris during the study. Materials included the game Minecraft ® on an electronic tablet, and non-preferred toys identified by indirect assessment. Chris's father agreed to withhold access to the tablet for 30 min after the last session of each visit, but he was not asked to otherwise withhold the tablet outside of sessions.

Paul was a 4-year-old Caucasian boy with secondary diagnoses of encephalopathy and attention deficit hyperactivity disorder. He attended an inclusive preschool program for children with disabilities three hours per day, five days per week, and his parents had incorporated ABA-based strategies into their interactions with him at home based on training in ABA they received from a BCBA. Throughout the study Paul was taking a fish oil capsule and 2 capsules of Vayarin in the morning daily, and 1.5 mg melatonin and 8mg naltrexone cream in the evening daily, and did not receive a special diet or other medication. Paul's mother was trained and participated in all sessions with guidance from the experimenter.

DEPENDENT VARIABLES AND MEASUREMENT

Manding and challenging behavior were primary dependent variables in the treatment evaluation. Challenging behavior was the dependent variable during the FA.

Echoics were measured during the duplic assessment. Data was collected on dependent variables only when the programmed establishing operation was present.

Response Definitions

The definition of a mand topography was individualized for each participant based on their repertoire. A mand topography was defined as a single word for William, a sentence consisting of three or more words for Chris, and a one or more word(s) utterance for Paul. An *independent variant mand topography* was defined as an independent vocal mand topography that differed from the last independent mand topography within the session. An *independent invariant mand topography* was defined as an independent vocal mand topography that was not different from the last independent mand topography within the session. Whether a mand topography was different, was defined individually for each participant.

For William, a mand topography was different if the word was different from the last word he used independently. For example, if he said “wait” after saying “rest” across two consecutive trials within the session, “wait” would be different, and therefore count as an independent variant mand topography. However, the second instance of saying “wait” on two consecutive opportunities to request the reinforcer would be considered an independent invariant mand topography.

For Chris, a mand topography was different if at least 2/3 words differed from the last sentence used independently. The word “please” established a sentence as different only when it occurred in the sentence “my turn please”. Otherwise, the word “please” did not establish a sentence as different. For example, if he said “Can I have it?” followed by

“Please can I have it?”, the latter was considered invariant. Similarly, if he said “my turn please” then “my turn please please please”, the latter was considered invariant and repeated “please” instances were not recorded in the transcript. One- and two-word utterances were not counted. Also, if the first sentence was “I want it” and the second sentence was “Can I have it?”, the second sentence was considered variant, despite the common word “it”.

For Paul, a mand topography was considered different if at least one word was different from the last word or words he used when subtracting common words from the current utterance and its preceding utterance. For example, if he said “No” then said “No, I’m busy!” then “I’m still busy!”, the second and third utterances would be considered different and therefore variant. If Paul’s fourth response was “I’m busy” it would be considered invariant.

Prompted variant mand topography was defined as a prompted mand topography which differed from the last independent mand topography within the session. Thus, in some sessions the same prompt was delivered across successive trials as long as the topography being prompted differed from the last mand topography that occurred independently.

The first independent mand topography of each session of the treatment evaluation was not measured for the purpose of calculating variant or invariant manding rates, but was measured to calculate the overall manding rate and also served as the basis for determining the variability of the second mand topography that occurred within the session. To evaluate the effects of the independent variable on the variant dimension of responding independent of language-related constraints, the response form did not need to be one commonly used to request the reinforcer by typically developing children. For example, when the lag schedule was in effect during the treatment evaluation, if instead of saying “wait” the participant said “water”, the response would have been reinforced. Prior research suggests the inclusion of contextually inappropriate mand topographies into the operational definition will not produce significant contextually inappropriate topographies (Silbaugh et al., submitted). Each session, independent variant mand topographies, independent invariant mand topographies, prompted variant mand topographies, and total mand topographies (i.e., variant plus invariant) were counted and converted to responses per minute.

Challenging behavior was defined individually for each participant. For William, challenging behavior was defined as crying and falling to the floor, actual or attempted elopement by walking five or more steps away from the adult’s reach, or aggression (pushing the adult with his hands, pushing or throwing self onto adult, kicking the adult, actual or attempting biting the adult). Crying or whining was not counted if it did not co-occur with falling to the floor. For Chris it was defined as including either whimpering consisting of non-words, kicking feet rapidly, tensing of the torso as indicated by bending forward while shaking, tensing of the hands into a cramped or fist-like position or flapping the hands, stomping feet, hitting furniture with hand, self-injury (hitting tailbone or buttocks on floor, or banging head on floor) or elopement (running to another room, consisting of at least 5 steps away from adult). For Paul it was defined as actual or attempted physical contact without permission (e.g., kicking, hitting, head butt, pushing, pulling hair, swinging arms at or rolling into the adult), hitting self on head or face with hand or fist, drop to floor, stomping feet, or pushing or throwing furniture or tangibles not designed to be thrown (e.g., chair, toy lighthouse). For all participants, all instances separated by 2 s without the behavior were counted. For all participants, the total count per session was converted to responses per minute.

INTEROBSERVER AGREEMENT

A trained observer independently viewed videos and coded data during 33% of sessions randomly selected across all phases of the treatment evaluation to assess interobserver agreement (IOA) using the exact count-per-interval method (Cooper et al., 2007). Each recording period (i.e., a session) was divided into 10-s intervals, and the number of intervals in which both observers recorded the same number of responses was totaled and divided by the total number of intervals, and the quotient was converted to a percentage. Mean IOA was calculated by summing session IOAs and dividing the total by the number of sessions. For William, mean IOA was 98% (range, 91%-100%) for independent variant manding, 98% (range, 94%-100%) for independent invariant manding, 96% (range, 81%-100%) for prompted variant manding, and 93% (range, 87%-100%) for challenging behavior. For Chris, mean IOA was 96% (range, 74%-100%) for independent variant manding, 93% (84%-100%) for independent invariant manding, 98% (range, 84%-100%) for prompted variant manding, and 95% (65%-100%) for challenging behavior. For Paul, mean IOA was 93% (range, 77%-100%) for independent variant manding, 95% (range, 87%-100%) for independent invariant manding, 99% (range, 90%-

100%) for prompted variant manding, and 97% (range, 84%-100%) for challenging behavior.

EXPERIMENTAL DESIGN AND INDEPENDENT VARIABLES

Phase 1: Functional Behavior Assessment

An FBA was conducted for all participants to generate hypotheses about the function(s) of challenging behavior that could be tested experimentally using FA. The FBA (i.e., Cipani & Schock, 2011) included common indirect and direct assessment methods such as semi-structured interviews, descriptive assessment, structured assessment, and extinction-analyses (William and Chris only) of the behavior in the context in which it was observed and/or reported by caregivers to occur.

Stage 2: Functional Analysis

An FA (e.g, Iwata et al., 1982/1994) was conducted to identify function(s) of challenging behavior to be incorporated into the treatment evaluation for each participant. Each FA continued until (a) differentiated data indicated one or more functions of challenging behavior based on at least three data points collected in each test and control condition, (b) the experimenter exhausted a reasonable number of strategies to enhance differentiation, or (c) time constraints did not permit continuing the assessment. A paired-stimulus preference assessment (Fisher et al., 1992) was used to identify a preferred tangible item to include in the tangible test condition of the FA for William.

William and Chris

A multielement design with a control condition and four test conditions was conducted to identify the function(s) of challenging behavior. Test and control conditions were 5 min in duration. The experimenter wore a discriminative stimulus (plain clothes, or an orange, blue, green, or purple shirt) associated with each condition. During the *control* condition the experimenter did not present demands. He gave the participant free access to an electronic tablet, delivered 2-3 s of attention on a fixed-time 15 s schedule (FT 15 s), and ignored challenging. During the *ignore* condition, the experimenter did not make toys or activities available, and he withheld attention for the duration of the session. Prior to the *tangible* condition, the experimenter gave the participant free access to the tablet for 1 min, and then started the session. Throughout the session, the experimenter said “my turn”, obtained the tablet using least-to-most prompting, and provided 30 s access to the tablet contingent on each instance of challenging behavior. For William, following the last tangible session of a home visit, he was told “I’m going to put the tablet away” and it was hidden out of sight for at least 30 min. During the *attention* condition, the tablet was placed out of sight. The participant was provided with attention and free access to low preferred toys (identified by PS-SPA for William, and parent report for Chris) for 1 min. Then, the experimenter said that he was busy but that the participant could play with the toys. Then the experimenter withdrew attention, and delivered 30-s attention on an FR 1 schedule contingent on each instance of challenging behavior. During the *demand* condition, the experimenter did not present the participant with toys or activities. For William, demands consisted of 1-step instructions related to transitions such as “it’s time to work, come sit down” and “come here” and “stand up”.

For Chris, demands consisted of 1-step instructions related to familiar household routines such as assisting with laundry or throwing trash in the trash can. The experimenter presented demands at 2 s ITI using a least-to-most prompting hierarchy (i.e., verbal, gestural/model, physical), and praised all instances of compliance. Escape was provided in the form of task termination for 30 s contingent on each instance of challenging behavior.

Paul

It was noted during the records review that Paul's current service provider conducted a multielement FA of challenging behavior prior to the study. The results of that FA suggested that challenging behavior was multiply maintained by attention, tangibles, and escape from demands. However, the provider also reported that challenging behavior occurred often during reinforcement intervals across test conditions. Additionally, the provider and Paul's mother reported that challenging behavior was easily evoked by transitions (e.g., asking Paul to momentarily discontinue one activity to complete another). Through direct assessment, the experimenter failed to establish a control condition (i.e., for standard FA test conditions) with zero levels of challenging behavior, largely due to apparent changes in the strength of EOs for items and activities as indicated by challenging behavior co-occurring with mands for items not present in the designated session room. Therefore, to control for fluctuations in EOs across conditions of the FA (e.g., Hagopian, Bruzek, Bowman, & Jennett, 2007), a FA was conducted to evaluate a potential functional relation between challenging behavior and the termination of interruptions of Pauls' ongoing activities (Fisher, Adelinis, Thompson, Worsdell, & Zarcone, 1998).

The FA utilized a pairwise design (Iwata et al., 1994) with a control condition and an interrupt condition. Sessions were 5 min in duration. A discriminative stimulus (yellow shirt) worn by the experimenter was associated with the interrupt condition. Common procedures included that sessions were conducted in any room of his home that Paul wanted to play in, Paul's mother was available to implement all aspects of the protocol except for interruptions, Paul was permitted to bring any toys or foods into sessions, and sessions began after 1 min without challenging behavior. During the *control* condition, Paul was not interrupted, minor attention (e.g., "okay") was given if he commented or described his play, his mother and the experimenter complied with all mands on an FR 1 schedule, and every 30 s the experimenter issued a brief reminder that he was available if Paul needed anything. If a mand was unsafe or impossible to provide, the experimenter made a best attempt to provide an approximate reinforcer corresponding to the mand (e.g., Hagopian et al., 2007). For example, on multiple occasions Paul asked the experimenter to go to his car and drive home, and the experimenter acted and made sound effects as if he were actually doing so. If challenging behavior occurred, interactions with Paul continued as if the challenging behavior did not occur (i.e., no differential consequences for the behavior). During the *interrupt* condition, the experimenter initiated trials by interrupting Paul and beginning to direct activities by saying something such as "okay let's go do something else" or "that's enough pirate's booty, let's do some work" or "put that down and sit at the table" and using LTM to separate Paul from access to tangibles. “Do” and “Don’t” interruptions were not systematically controlled for as in prior interrupt FAs (e.g., Fisher et al., 1998; Hagopian et al., 2007, Study 2). During interruptions, mands were placed on extinction, and contingent on challenging behavior, the experimenter immediately terminated the interruption while saying something such as “okay you don’t have to”, and for 30 s the adults began complying with mands on an FR 1 schedule. Any challenging behavior that occurred during the reinforcement interval would have been ignored, however, none occurred.

Phase 3: Duplic Assessment

The purpose of this assessment was to demonstrate participants could emit the alternative target mand topographies prior to the treatment evaluation. No items or activities were accessible during the assessment. Echoic responses were measured for William and Chris. Multiple novel response-effort-equivalent alternative response topographies corresponding to the reinforcer maintaining challenging behavior were assessed in a discrete trial format, for 3 trials per target response. The participant was seated for the assessment. A trial began when the experimenter said “copy me”, “say what I say”, or other verbal prompts previously determined to be effective at evoking duplic, and ended when 5 s passed without a correct response or the participant responded correctly. Correct responses were praised (e.g., Awesome, you said it!”). Target responses were randomly interspersed across trials. Trials were separated by 2-3-s intertrial intervals. All three trials for each target mand topography was conducted in a single session for William and over two sessions for Chris. A response was targeted in the treatment evaluation if the participant responded correctly on all 3 trials. The assessment for each participant ended when 3 target responses were identified. Paul refused to discontinue ongoing activities, comply with basic instructions to sit at a table, or echo arbitrary phrases stated by the experimenter, all of which were prerequisites to beginning the assessment. Therefore, Paul was advanced directly to the treatment evaluation following completion of his FA. For William, the topographies “wait”, “stop”, and “rest” where identified as targets to be prompted during the treatment evaluation. For Chris, the topographies “are you done?”, “is it time?”, and “my turn please” were identified as targets to be prompted during the treatment evaluation.

Phase 4: Treatment Evaluation

Reversal designs were used to evaluate the effects of FCT plus a Lag 1 schedule of reinforcement with prompting procedures on challenging behavior and topographical mand variability.

FR 1

Procedures in this condition were identical to the corresponding test condition of the FA.

FCT + Lag 0

Only Paul was exposed to this condition. Procedures were similar to FR 1, with some exceptions. Challenging topographies were placed on extinction and every instance of an appropriate vocal mand topography was reinforced without a requirement to vary. Prompting and rapid prompt fading was added to two sessions to increase contact between vocal mands and the programmed reinforcer. Specifically, Paul was prompted to say “I’m busy” (i.e., a response within his repertoire).

FCT + Lag 1 + TD

Only William and Chris were exposed to this condition. Procedures were similar to the FCT + Lag 0 condition, with multiple exceptions. Independent and prompted variant target mand topographies were differentially reinforced on a Lag 1 schedule of reinforcement. Specifically, a mand topography was reinforced if it differed from the last independent mand topography within the session (Silbaugh et al., submitted).

For the first 6 trials of the first session of the first phase, the experimenter delivered a prompt for a variant vocal mand less than 2 s following the onset of the establishing operation. On the 7th trial, a 2-s TD was introduced if all prior trials consisted of invariant mand topographies or prompted variant mand topographies. During the 2-s TD, if a variant mand topography did not occur within 2-s of the establishing operation, the experimenter modeled a target variant mand topography selected quasi-randomly (e.g., “wait”, “rest”, or “stop” William, and “my turn please”, “are you done” or “is it time” for Chris). The prompt was re-delivered every 2 s (i.e., the trial was extended) until the target variant mand topography occurred. The length of the TD was increased by 2-s every six consecutive trials that a target variant mand topography did not occur independently. Increases in the length of the TD were permitted to occur within and between sessions, but not across. Thus, if the last five mand topographies for a session were invariant, the length of the TD did not increase until six consecutive invariant mand topographies occurred in the subsequent session. The first session of all subsequent FCT

+ Lag 1 + TD phases began with the last effective TD. If at least three consecutive sessions with low or no independent variant manding occurred (e.g., 0.5 times per minute), a probe session without prompts (based on the results of Experiment 1) was conducted. The TD was held constant at 2 s for the last three sessions of the first FCT + Lag 1 + TD for Chris to assess the effects of this variation of the TD on manding and challenging behavior.

No-Prompt Probe

Only William and Chris were exposed to this condition. Procedures were similar to those used in the FCT + Lag 1 + TD and FCT + Lag 0 + TD conditions, except that no prompts were delivered. If the probe was conducted within an FCT + Lag 1 + TD phase, and an immediate within-session increase in the rate of variant manding was observed, suggesting variant manding was under the control of the relevant EO, prompts were discontinued for subsequent sessions while the programmed reinforcer continued to be delivered contingent on instances of variant vocal mand topographies (i.e., FCT + Lag 1). The purpose of this condition was to provide the participant with longer contact with extinction for invariant manding to increase the likelihood that extinction-induced variability would contact the lag schedule. Alternatively, if the probe was conducted within an FCT + Lag 0 + TD phase (William only), every independent mand topography was reinforced and there was no requirement to vary. This condition allowed for an assessment of stimulus control over manding by the EO for the programmed reinforcer.

FCT + Lag 1

Procedures were similar to the FCT + Lag 0 condition, with one exception. Independent variant target mand topographies were differentially reinforced on a Lag 1 schedule of reinforcement. Specifically, a mand topography was reinforced if it differed from the last independent mand topography within the session.

FCT + Lag 0 + TD

Procedures in this condition were similar to the FCT + Lag 1 + TD condition, with some exceptions. For the first session (including subsequent re-introductions of this condition), the experimenter errorlessly prompted a single vocal mand topography in the participant's repertoire (e.g., "no" for William, "I want it" for Chris) for the first six trials. Beginning with trial 7, the 2-s TD was introduced and any independent mand topography was reinforced on a Lag 0 schedule (i.e., variant manding was not required to produce the reinforcer).

Chapter 4: Results

In this chapter, the results of experiments 1 and 2 and described…

EXPERIMENT 1

The results of the multielement FA for Zahid are displayed in Figure 3. The data were undifferentiated (*M* = 0 RPM), play condition; *M* = 0.2 RPM, attention condition; *M* = 0 RPM, escape condition; *M* = 0.1 RPM, ignore condition). The results of the pairwise FA for Zahid are displayed in Figure 4. Levels of challenging behavior were consistently elevated in the tangible condition (*M* = 0.8 RPM) relative to the play condition (*M* = 0.1 RPM).

The results of the treatment evaluation are displayed in Figure 5. During FR 1 (i.e., baseline reinforcement of challenging behavior), elevated efficient rates of challenging behavior (*M* = 1.25 RPM) were observed, but manding was not observed. Upon introduction of FCT + Lag 1 + TD, rates of challenging behavior reduced to zero levels until progressive TD was introduced. As the TD increased from 2- to 6-s across sessions, rates of challenging behavior (*M* = 0.24 RPM) gradually approached baseline levels and rates of independent manding remained at zero levels despite an increase in the level of prompted variant manding rates (*M* = 1.16 RPM). With the phase change to FCT + Lag 1 + LTM, rates of challenging behavior (*M* = 0.76 RPM) and prompted manding (*M* = 1.24 RPM) continued at the level observed when prompts were faded using TD, with no changes in rates of independent manding (*M* = 0 RPM of total manding). Coinciding with the phase change to FCT + Lag 0, the level of challenging behavior rates returned to baseline (*M* = 1.41 RPM). In addition, rates of independent invariant manding gradually increased across sessions (*M* = 0.89 RPM) while rates of variant manding remained at near zero levels (*M* = 0.03 RPM). Upon reintroduction of FCT + Lag 1 + TD, an increasing trend in rates of challenging behavior (*M* = 0.90 RPM) and a decreasing trend in rates of independent manding (*M* = 0.26 RPM of total independent manding) were observed. In the next phase the TD was omitted from FCT + Lag 1 for a no-prompt probe session which coincided with the first large increase in variant manding, a return to prior elevated levels of invariant manding, and a reduced rate of challenging behavior. As the condition was continued in the absence of prompts (i.e., FCT + Lag 1), continued elevated levels of independent variant (*M* = 0.78 RPM) and invariant manding (*M* = 1.56 RPM) were observed, as well as highly variable and wide ranging rates of challenging behavior (*M* = 2.67 RPM). A return to FCT + Lag 0 then coincided with an immediate reduction in the rates of challenging behavior (*M* = 0.2 RPM) and variant manding (*M* = 0 RPM), with no change in rates of invariant manding (*M* = 1.28 RPM). Upon reintroduction of the final FCT + Lag 1 phase, rates of challenging behavior gradually increased across sessions (*M* = 0.44 RPM) coinciding with a continuation of the prior rates of independent invariant manding (*M* = 1.0 RPM) and a return to elevated rates of independent variant manding (*M* = 1.14 RPM) observed only during FCT + Lag 1 sessions.

Table 5 summarizes prompted and independent vocal mand topographies observed during the treatment evaluation. All three target alternative vocal mand topographies occurred independently. The most frequently occurring topographies, in descending order were “will you share”, “I’m still playing” and “not yet (therapist name)”.

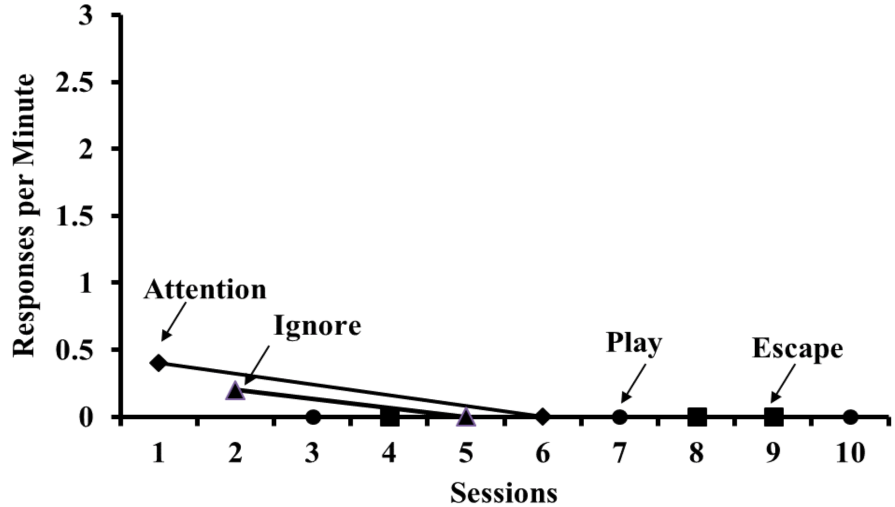

Figure 3. Responses per minute of challenging behavior during attention, ignore, play, and escape conditions of the multielement functional analysis for Zahid.

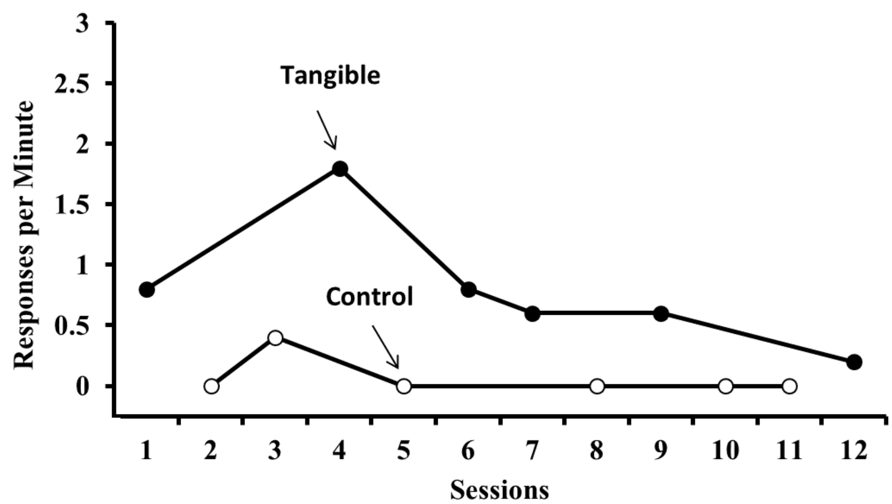

Figure 4. Responses per minute of challenging behavior during tangible and control conditions of the pairwise functional analysis for Zahid.

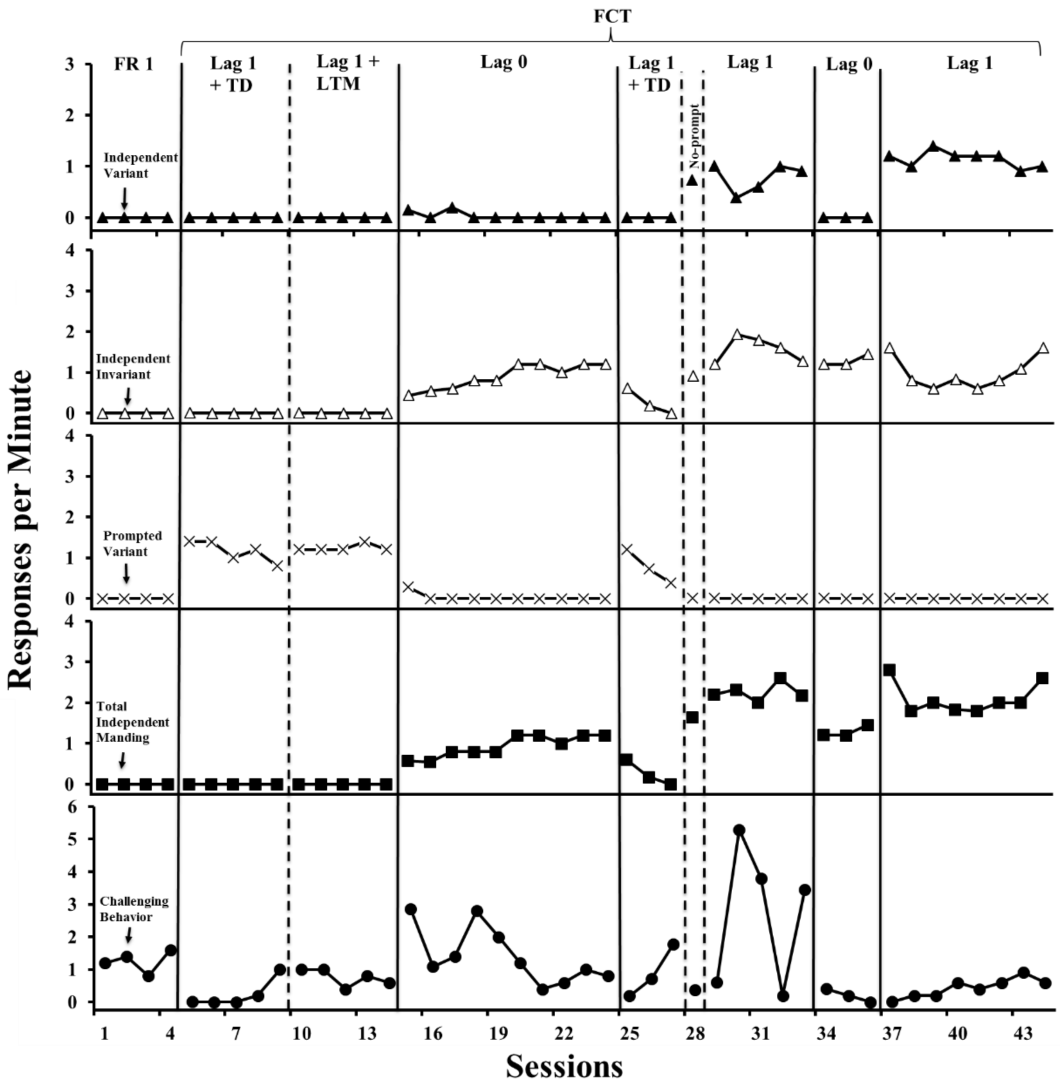

Figure 5. Responses per minute of independent variant, independent invariant, prompted variant, and total independent manding (panels 1 – 4), and challenging behavior (panel 5) across phases of the treatment evaluation for Zahid.

Table 5.

Counts of mand Topographies that Occurred during the Treatment Evaluation for Zahid.

Topography	Total Count
Will you share*	200 (180, 20)
I'm still playing	46 (46, NA)
Not yet (therapist name)*	25 (8, 17)
Let me play*	31 (3, 28)
Can I have that please	1 (1, NA)
Okay will you share	1 (1, NA)
I want the Dora	1 (1, NA)
Say not yet (therapist name)	1 (1, NA)

Note. Values outside parentheses represent counts of prompted and independent instances that occurred, and include the first response on each trial of each session, which was not included in the calculation of manding rates. Within parentheses, the first value represents total independent instances and the second value represents total prompted instances across all sessions of the treatment evaluation. NA = The topography was never prompted. * A target topography prompted during the treatment evaluation.

EXPERIMENT 2

William

The results of the paired stimulus preference assessment are displayed in Figure 6. iPad ® was identified as a high preferred stimulus. The results of the multielement FA are displayed in Figure 7. Levels of challenging behavior were consistently elevated in the escape (*M* = 1.4 RPM) and tangible (*M* = 0.5 RPM) conditions relative to the control condition (*M* = 0 RPM). Levels of challenging behavior in the ignore (*M* = 0 RPM) and attention conditions were equal to the control condition (*M* = 0 RPM). As summarized in Table 6, during the treatment evaluation a total of four different independent vocal mand topographies were observed. All topographies that were prompted, ultimately occurred independently as well.

The results of the treatment evaluation are displayed in Figure 8. During FR 1, steady efficient rates of challenging behavior (*M* = 1.53 RPM) were observed, but no manding was observed. Upon introduction of FCT + Lag 1 + TD, little change independent manding (*M* = 0.1 RPM) was observed. The level of prompted variant manding increased (*M* = 1.1 RPM), and a reduction in the level of challenging behavior (*M* = 0.8 RPM) was observed. Two no-prompt probes were embedded in this phase. In the first probe, no changes in independent manding rates were observed, and a large increase in the rate of challenging behavior was observed. Similarly, in the second probe no changes in independent manding rates were observed, but the rate of challenging behavior decreased to zero. Upon a phase change to FCT + Lag 0 + TD, no changes in dependent variables other than a slight increase in prompted variant manding rates (*M* =

1.6 RPM), were observed. In the reversal to FR 1, increased rates, but a decreasing trend, in invariant manding (*M* = 1.07 RPM) was observed and was associated with a replication of the steady efficient rates of challenging behavior (*M* = 1.53 RPM) observed in the first FR 1 phase. Upon reintroduction of FCT + Lag 0 + TD, a shift to an increasing trend was observed for invariant manding (*M* = 1.2 RPM) and challenging behavior reduced to zero rates. A phase change to FCT + Lag 1 + TD was associated with a brief transient increase in rates of variant manding (*M* = 0.1 RPM), a decrease in invariant manding rates (*M* = 1.07 RPM), elevated rates of prompted variant manding (*M* = 1.13 RPM), decreased total independent manding (*M* = 0.63 RPM), and rates of challenging behavior were near zero. During a no-prompt probe session embedded in this phase, the rate of invariant manding was unchanged, but a slight decrease in total independent manding and a return to elevated levels of challenging behavior were observed.

Chris

The results of the multielement FA are displayed in Figure 9. Levels of challenging behavior were consistently elevated in the tangible condition (*M* = 1.7 RPM) relative to the control (*M* = 0 RPM) condition. Challenging behavior was absent in the remaining test conditions (i.e., *M* = 0 RPM, attention condition; *M* = 0 RPM, escape condition; *M* = 0 RPM, ignore condition). As summarized in Table 6, during the treatment evaluation a total of 13 different independent vocal mand topographies were observed. All topographies that were prompted, ultimately occurred independently as well.

The results of the treatment evaluation are displayed in Figure 10. During FR 1 steady efficient rates of challenging behavior (*M* = 1.7 RPM) were observed, and no manding was observed. Coinciding with FCT + Lag 1 + TD, increased rates of prompted responses (*M* = 1.67) and a shift to an increasing trend in challenging behavior rates (*M* = 1.65 RPM) were observed, but no changes in independent manding rates (*M* = 0.1 RPM), were observed. Within this phase, two no-prompt probes were conducted. During the first probe, a large increase in the rate of challenging behavior was observed, but manding rates were unchanged. As the length of the TD was held constant, challenging behavior rates decreased (*M* = 0.7 RPM), prompted manding rates were constant (*M* = 1.2), and almost no change in the rates of independent manding (*M* = 0.4 RPM) were observed. During the second probe, no changes in dependent variables were observed. Upon introduction of FCT + Lag 0 + TD, as the length of the TD increased, challenging behavior rates reduced to zero levels, independent variant (*M* = 0.36 RPM) and invariant (*M* = 0.76 RPM) manding rates increased and stabilized at no trend as the rate of prompted variant manding (*M* = 0.56 RPM) decreased across sessions. Upon the introduction of FCT + Lag 1 + TD, independent variant (*M* = 0.8 RPM) and invariant (*M* = 2.05 RPM) manding rates steadily increased across sessions coinciding with a slight decrease in rates of prompted variant manding (*M* = 0.75 RPM) as challenging behavior continued at zero rates. However, a large increase in the rate of challenging behavior was observed during a no-prompt probe within this phase. Rates of challenging behavior remained at or near zero levels for the rest of the treatment evaluation. Upon the withdrawal to FCT + Lag 0 + TD, independent invariant manding rates (*M* = 2.27 RPM) maintained as independent variant manding rates (*M* = 0.53 RPM) gradually decreased, the level of total independent manding decreased (*M* = 3.0 RPM), and prompted variant manding occurred at zero rates. When FCT + Lag 1 + TD was re-introduced, a replication of increasing rates of independent variant manding (*M* = 1.12 RPM) across sessions was observed. Additionally, although the level of responding was unchanged, a shift to a decreasing trend in rates of independent invariant manding (*M* = 3.0 RPM) was observed. A similar pattern was observed for total independent manding (*M* = 4.32 RPM), and an increase in the level of prompted manding rates ((*M* = 0.4 RPM) was observed. No changes in dependent variables were observed during a no-prompt probe session. When the TD procedure was withdrawn in the final FCT + Lag 1 phase, high rates of independent variant manding (*M* = 1.7 RPM) continued as independent invariant manding (*M* = 1.2 RPM) steadily decreased.

Paul

The results of the interrupt FA are displayed in Figure 11. Levels of challenging behavior were consistently elevated in the interrupt condition (*M* = 1.47 RPM) relative to the control condition (*M* = 0.08 RPM). As summarized in Table 6, during the treatment evaluation a total of 60 different independent vocal mand topographies were observed. The topography “I’m busy” was prompted and subsequently occurred independently.

The results of the treatment evaluation are displayed in Figure 12. During FR 1, rates of independent variant manding gradually decreased (*M* = 1.4 RPM), invariant manding rates (*M* = 1.9 RPM) showed a decreasing trend, there were no occasions to engage in prompted variant manding, total independent manding rates (*M* = 3.5) gradually decreased, and challenging behavior (*M* = 1.7 RPM) occurred at high steady rates. Upon introduction of FCT + Lag 0, a change in trend was observed for variant manding (*M* =0.8 RPM), invariant manding rates were constant (*M* = 1.4 RPM), there were no occasions for prompted variant manding, no changes in the rate or trend in total manding (*M* = 2.4 RPM) were observed, and rates of challenging behavior remained constant (*M* = 1.6 RPM). When prompting and prompt fading were added to the condition, an immediate decrease in rates of challenging behavior was observed (*M* = 0.3 RPM), accompanied by a decrease in independent manding (*M* = 0.6 RPM) and an increase in prompted manding rates (*M* = 1.1 RPM). Across subsequent sessions of the condition without prompting, a return to steady rates of variant manding (*M* = 1.0 RPM) was observed, accompanied by no change in invariant manding rates (*M* = 0.6 RPM), steady rates of total independent manding (*M* = 1.9 RPM), and a continuation of reduced challenging behavior rates (*M* = 0.5 RPM). Introduction of FCT + Lag 1 coincided with a small increase in the level of variant manding rates (*M* = 1.4 RPM), no change in invariant manding (*M* = 0.7 RPM), a small increase in the level of total independent manding (*M* = 2.2), and no change in rates of challenging behavior (*M* = 0.6 RPM). Upon return to FCT + Lag 0, rates of variant manding (*M* = 0.7 RPM) gradually reduced across sessions, coinciding with no changes in invariant manding rates (*M* = 0.9 RPM), reduced variability in independent manding rates (*M* = 1.7 RPM), and a reduction of challenging behavior to zero rates. Upon re-introduction of FCT + Lag 1, a return to slightly elevated and steady rates of variant manding was observed (*M* = 1.4 RPM), accompanied by an increase in the range of invariant manding rates (*M* = 1.4), an increase in the level of total independent manding (*M* = 3.0 RPM), and a slight increase in the level of challenging behavior rates (*M* = 0.3 RPM). FCT was withdrawn to FR 1, and a large immediate increase in the level of variant manding rates was observed (*M* = 3.9), coinciding with no changes in invariant manding (*M* = 1.1 RPM), an increase in total independent manding 5.2 RPM), and a return to baseline rates of challenging behavior (*M* = 1.7 RPM). Lastly, FCT + Lag 1 was re-introduced, which coincided with a return to previous slightly elevated but steady rates of variant manding (*M* = 1.5 RPM) observed in the prior FCT + Lag 1 condition, as well as an observed increase in the range of invariant manding, a slightly elevated level of total independent manding (*M* = 3.9) with an expanded range, and a replication of previously observed rates of challenging behavior (*M* = 0.6 RPM) reduced relative to baseline.

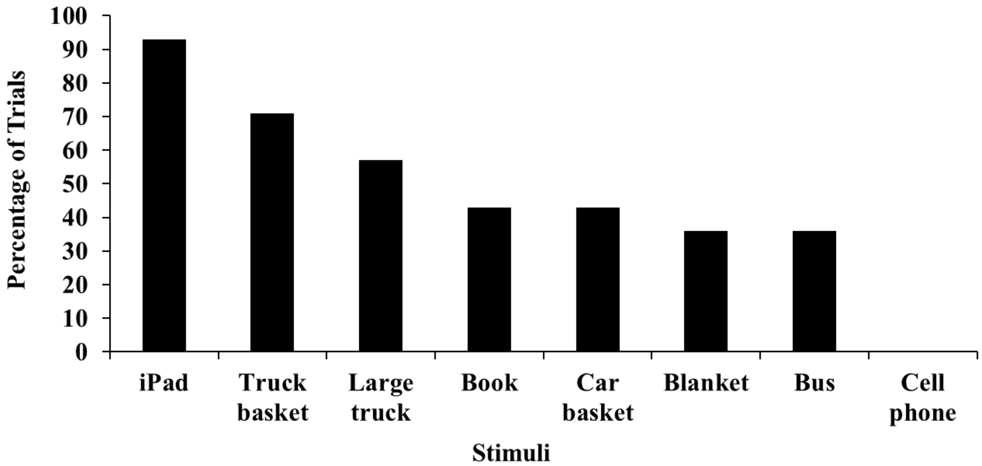

Figure 6. Percentage of trials in which each stimulus was selected during the paired-stimulus preference assessment for William.

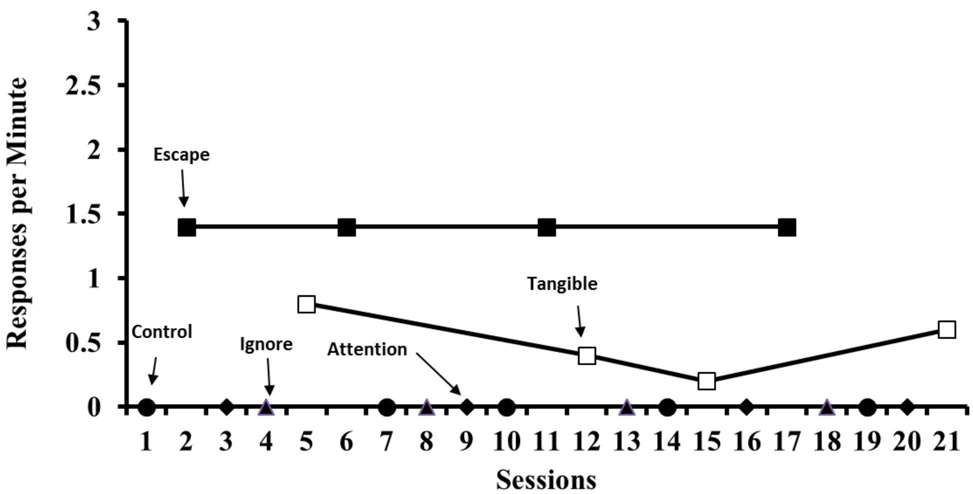

Figure 7. Responses per minute of challenging behavior during control, escape, ignore, attention, and tangible conditions of the multielement functional analysis for William.

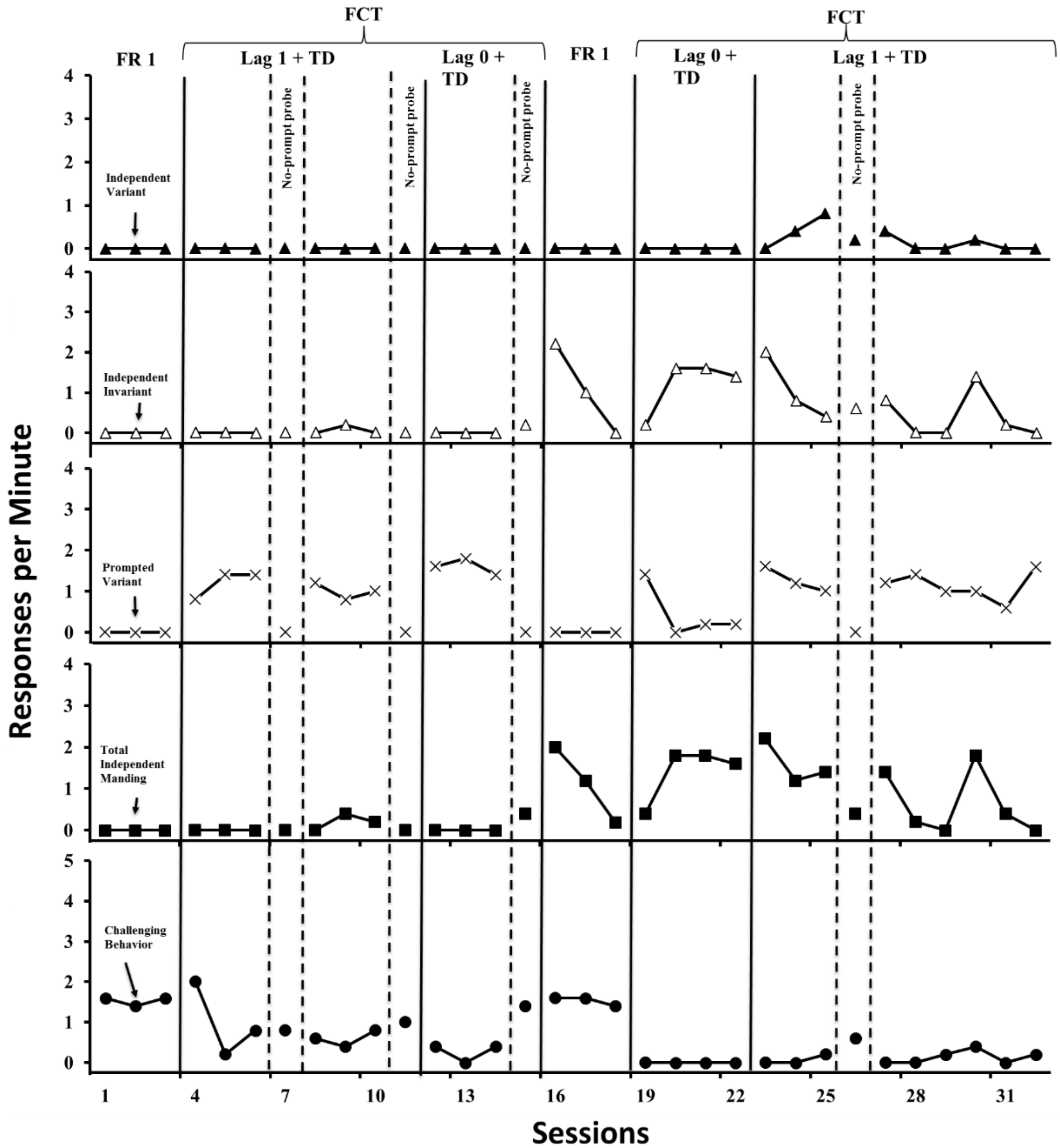

Figure 8. Responses per minute of independent variant, independent invariant, prompted variant, and total independent manding (panels 1 – 4), and challenging behavior (panel 5) across phases of the treatment evaluation for William.

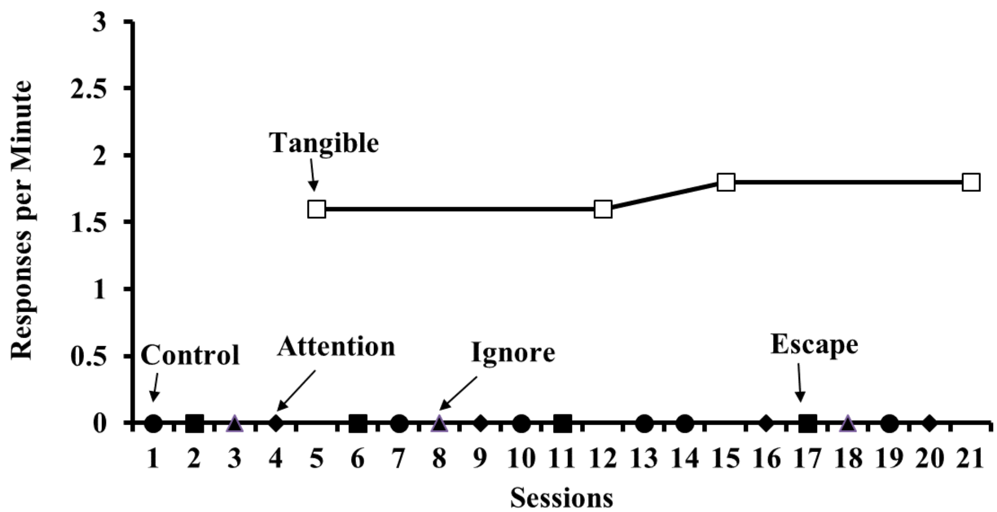

Figure 9. Responses per minute of challenging behavior during control, escape, ignore, attention, and tangible conditions of the multielement functional analysis for Chris.

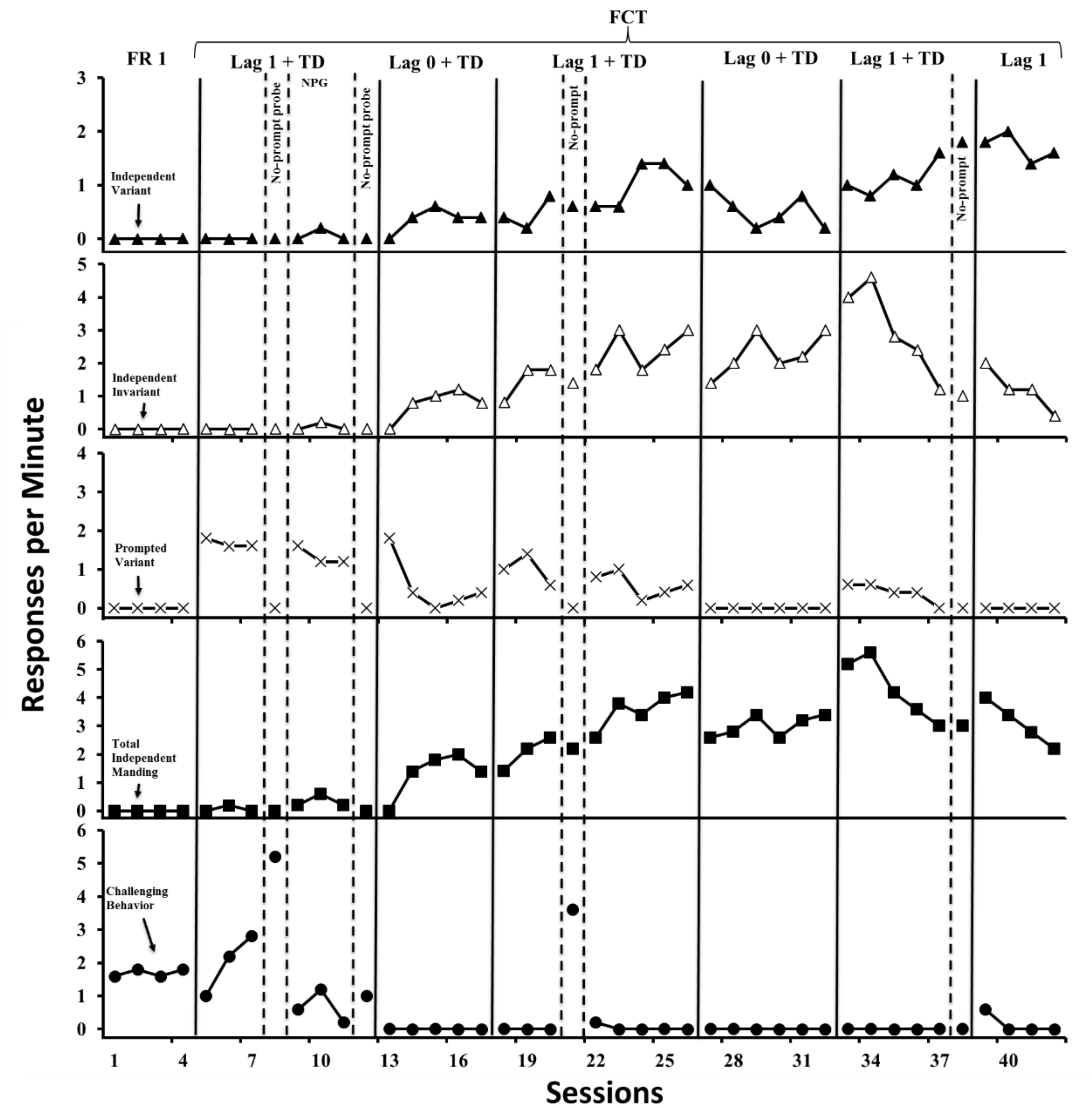

Figure 10. Responses per minute of independent variant, independent invariant, prompted variant, and total independent manding (panels 1 – 4), and challenging behavior (panel 5) across phases of the treatment evaluation for Chris. pg = progressive TD, npg = non-progressive TD (i.e., TD held constant at 2 s).

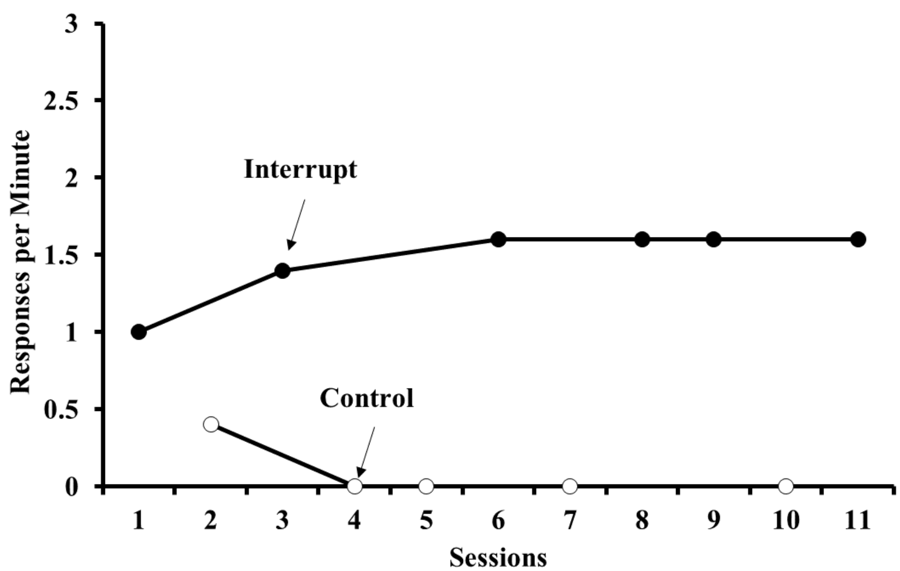

Figure 11. Responses per minute of challenging behavior during control and test conditions of the interrupt functional analysis for Paul.

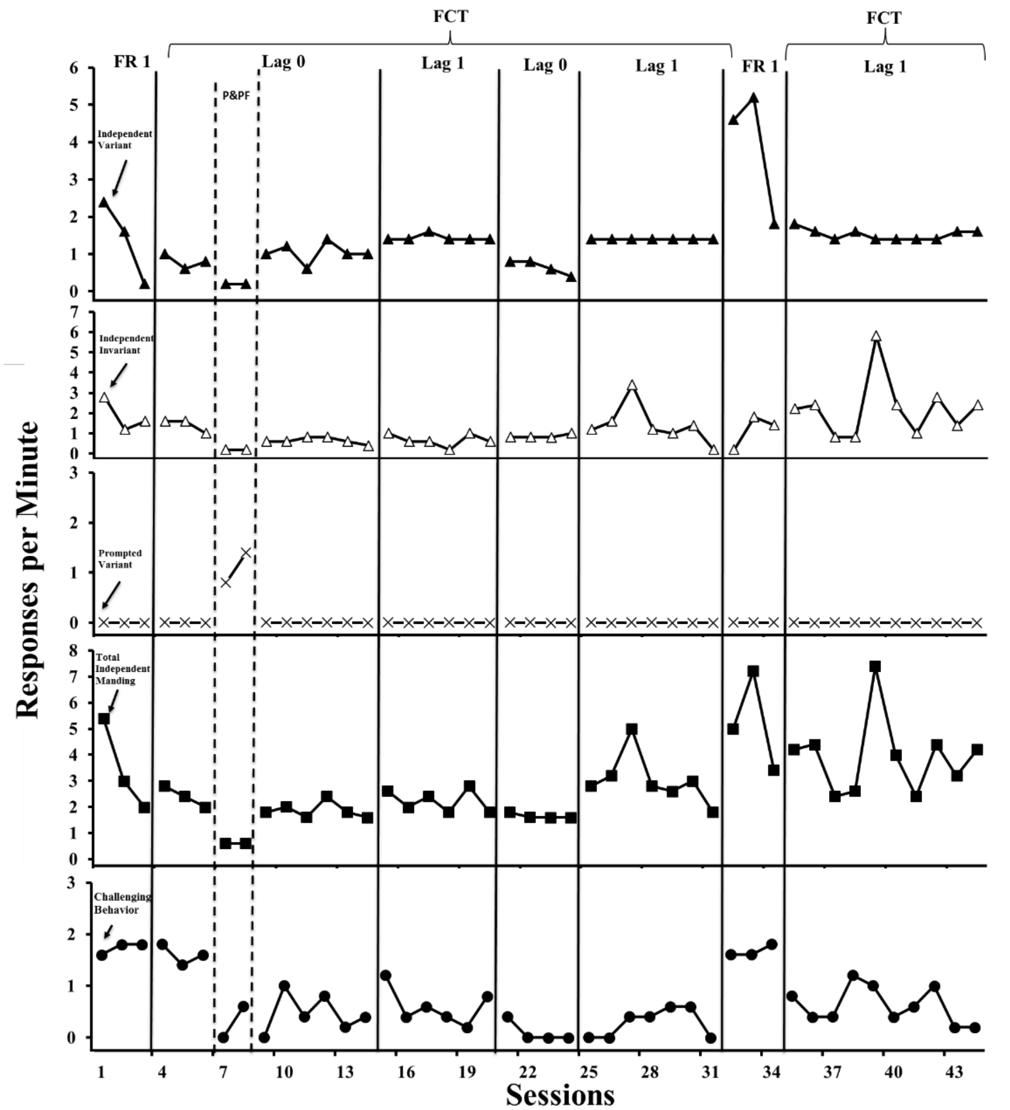

Figure 12. Responses per minute of independent variant, independent invariant, prompted variant, and total independent manding (panels 1 – 4), and challenging behavior (panel 5) across phases of the treatment evaluation for Paul. p&pf = prompting and prompt fading.

Table 6.

Counts of Mand Topographies that Occurred During the Treatment Evaluation for William, Chris, and Paul.

Participant	**Topography**	**Total Count**
William	No*	113 (86, 37)
	Wait*	41 (8, 33)
	Rest*	27 (3, 24)
	Stop*	34 (1, 33)
Chris	I want it	308 (294, 14)
	My turn please*	120 (105, 15)
	Is it time*	49 (22, 27)
	Can I have it	8 (8, NA)
	Are you done*	34 (4, 30)
	Is it time clock	2 (2, NA)
	Is it clock	1 (1, NA)
	Can I see it	1 (1, NA)
	I want it please	1 (1, NA)
	Help me please	1 (1, NA)
	Wait I want it	1 (1, NA)
	Help I want it	1 (1, NA)
	Is it my turn	1 (1, NA)

Note. Values outside parentheses represent counts of prompted and independent instances that occurred, and include the first response on each trial of each session, which was not included in the calculation of invariant or variant manding rates. Within parentheses, the first value represents total independent instances and the second value represents total prompted instances across all sessions of the treatment evaluation. Topographies are ordered from high to low based on independent instances. NA = The topography was never prompted. * A target topography prompted during the treatment evaluation.

Table 6.

Continued.

Participant	Topography	Total Count
Paul	No	355 (355, NA)
	Stop	88 (88, NA)
	Stop it	24 (24, NA)
	I’m not	22 (22, NA)
	I’m busy*	20 (1, 12)
	You stop	14 (14, NA)
	Stop now	13 (13, NA)
	No more	9 (9, NA)
	Stop it now	5 (5, NA)
	I said No	5 (5, NA)
	Please stop	4 (4, NA)
	I’m staying	4 (4, NA)
	Hey you stop	3 (3, NA)
	I don’t want to	2 (2, NA)
	No I’m busy	2 (2, NA)
	I say no	2 (2, NA)
	I’m busy first	1 (1, NA)
	Never	1 (1, NA)
	I’m not doing	1 (1, NA)
	You	1 (1, NA)
	Get out of my way	1 (1, NA)
	I need this fixed	1 (1, NA)
	No for you	1 (1, NA)
	Let me go	1 (1, NA)
	Me no	1 (1, NA)
	You go out of here	1 (1, NA)
	Shoo	1 (1, NA)
	You go	1 (1, NA)
	You get me out of here	1 (1, NA)
	You go now	1 (1, NA)
	Leave me alone	1 (1, NA)
	I not want to	1 (1, NA)
	Hey you stop it	1 (1, NA)
	No I’m staying	1 (1, NA)
	Let go	1 (1, NA)
	I don’t	1 (1, NA)
	I don’t like it	1 (1, NA)
	I say stop	1 (1, NA)

Table 6.

Continued.

Participant	Topography	Total Count
Paul	I'm taking my package	1 (1, NA)
	No I'm going	1 (1, NA)
	I'm stop	1 (1, NA)
	Gimmie my ___ and case	1 (1, NA)
	I'm not want to	1 (1, NA)
	No I need to walk the dogs	1 (1, NA)
	I need to let the dogs out	1 (1, NA)
	I hate it	1 (1, NA)
	No I'm staying here	1 (1, NA)
	Hey you	1 (1, NA)
	Hey give me that	1 (1, NA)
	Hey no	1 (1, NA)
	I'm not going	1 (1, NA)
	I'm not liking it	1 (1, NA)
	You are stopping	1 (1, NA)
	No this track is not good	1 (1, NA)
	Go now	1 (1, NA)
	I'm not going to do	1 (1, NA)
	Go	1 (1, NA)
	I said not	1 (1, NA)
	Stop tearing down my bridge	1 (1, NA)
	I'm breaking down the bridge	1 (1, NA)

Chapter 5: Discussion

In the current study, two experiments were conducted to evaluate the effects of FCT with lag schedules and prompting strategies on rates of topographical mand variability and challenging behavior. The primary finding was that conditions involving lag schedules coincided with the highest levels of independent variant vocal manding for three of four participants. During FCT experimental control over independent variant vocal manding was demonstrated by the lag schedule when prompts were eliminated for Paul and Zahid, and elevated rates maintained for Chris when prompts were eliminated from the lag schedule. Together, these findings suggest lag schedules may be used alone or in combination with response prompt fading strategies during FCT to reinforce topographical vocal mand variability, and extend the literature on mand variability, lag schedules, and FCT.

Based on Michael's (1985) conceptualization of topography-based speaker response forms, if a speaker's primary verbal modality is vocal, to consistently produce reinforcement with mands they must be able to both (a) use the same mand topography across instances when listener-mediated contingencies are selective for a narrow range of topographies (e.g., only one word will produce the reinforcer with any consistency), and (b) use different mand topographies across instances when listener-mediated contingencies change (i.e., when the speaker must say something different to obtain the same reinforcer). When contingencies in the environment are not programmed to support a variety of mands from a speaker with language delays or deficits, in some cases common mand training procedures can produce invariant manding (Carr & Kologinsky, 1983). Invariant manding may prevent the speaker from producing reinforcement under everyday conditions in which contingencies naturally vary (i.e., outside of highly controlled treatment environments). Despite this potential problem, only a small number of studies have evaluated functional relations between mand variability and environmental variables. Each study demonstrated increases in either mand variability or novel instances of manding across concurrently available reinforcers (i.e., across mands) during mand training for individuals with ASD (Bernstein & Sturmey, 2008; Betz et al., 2011; Broadhead et al., 2016; Carr & Kologinsky, 1983; Drasgow et al., 2015; Sellers et al., 2015) or intellectual disability (e.g., Duker & Lent, 1991). Alternatively, our group demonstrated that a Lag 1 schedule of reinforcement with progressive TD increased variability in the words children with ASD used to mand for the same reinforcer (i.e., topographical vocal mand variability; Silbaugh et al., submitted). However, a limitation of Silbaugh et al. was that the TD component was not completely withdrawn, and therefore the separate effects of the lag schedule and prompts could not be determined. The data from three participants in the current study addressed this limitation. For Chris, after experimental control over independent variant manding by FCT + Lag 1 + TD was demonstrated, elevated independent vocal mand variability continued during a no-prompt probe and during an FCT + Lag 1 phase in which prompts had been completely withdrawn. For Zahid, following a large immediate increase in independent variant vocal manding during a no-prompt probe, prompts were completely withdrawn, and experimental control over independent variant vocal manding by FCT + Lag 1 was demonstrated. For Paul, experimental control over independent variant vocal manding by

FCT + Lag 1 was demonstrated despite no prior prompts to vary. Although mand variability was reinforced in the current study in the context of FCT, the results may be generalizable to mand variability training in general.

A growing body of applied literature on the effects of lag schedules of reinforcement suggests operant variability in multiple skill domains can be reinforced in individuals with ASD, other DD, and/or intellectual disability. For example, following the seminal study (Lee, McComas, &Jawor, 2002), which showed a lag schedule increased variability in answers to social questions in individuals with ASD. studies have shown lag schedules with or without prompts have similar effects on variability in tacts (Heldt & Schlinger, 2012), feeding (Silbaugh & Falcomata, 2016; Silbaugh, Wingate, & Falcomata, 2016), naming members of a category under group contingencies (Wiskow & Donaldson, 2016), play skills (e.g., Baruni, Rapp, Lipe, & Novtny, 2014), vocalizations (e.g., Esch, Esch, & Love, 2009), responses to interview questions (O'Neill & Rehfeldt, 2014), conversational topics (Lepper, Devine, & Petursdottir, 2016), and mand frames (Brodhead et al., 2016). Only one prior study has evaluated the effects of lag schedules on mand variability and challenging behavior during FCT (Adami et al., 2017). The current study represents a valuable extension of the applied lag schedule literature by differing in several ways from Adami et al., thereby allowing for an examination of the generality of the effects of lag schedules combined with FCT. First, the current study included younger participants. Second, Adami et al. reinforced variability in manding across non-vocal, largely selection-based, mand modalities (e.g., tablet, a card to exchange), whereas the current study demonstrated how to use lag schedules alone or in combination with response prompt fading to reinforce variability in vocal, topography-based manding. Third, Adami et al. did not use prompts, whereas the current study systematically evaluated the use of response prompt fading to establish contact between mand variability and the lag schedule. Forth, the current study measured associated changes in independent invariant manding, which were not assessed in Adami et al (2017). Fifth, Adami et al. included individuals with challenging behavior maintained by either tangibles or escape from task demands. In the current study, increased vocal mand variability under the control of the lag schedule during FCT was demonstrated not only for individuals with challenging behavior maintained by tangibles and/or escape from task demands, but also for one participant for whom challenging behavior was maintained by termination of interruptions. Lastly, the current study used a more conservative measure of interobserver agreement, which warrants greater confidence in the integrity of the dependent variables.

Since the seminal study of FCT by Carr & Durand (1985), FCT research has focused on differentially reinforcing a single (e.g., Brown et al., 2000; Durand & Carr, 1992; Fisher et al., 1998; Kahng, Iwata, DeLeon, & Worsdell, 1997; Kelley, Lerman, & Van Camp, 2002; Lalli et al., 1995; Shirley, Iwata, Kahng, Mazaleski, & Lerman, 1997; Volkert et al., 2009; Worsdell, Iwata, Hanley, Thompson, & Kahng, 2000), or multiple (e.g., Hagopian, Kuhn, Long, & Rush, 2005, participant “Stephen”; Harding et al., 2009; Richman, Wacker, & Winborn, 2001; Wacker et al., 1990, participant “Jim”) alternative socially appropriate communication responses (i.e., selection-based mand or topography-based mand) to request the reinforcer previously produced by challenging behavior.

However, only one study directly measured variability in functional communication responses (Adami et al., 2017), so existing literature does little to inform our knowledge about effects on mand variability during the treatment of challenging behavior. Zero rates of variant manding were demonstrated during FCT Lag 0 for both participants in Adami et al., and in the current study, Zahid demonstrated zero rates of independent variant manding during FCT Lag 0 even though he previously demonstrated multiple independent vocal mand topographies were in his repertoire. Invariant manding produced by FCT may be clinically contraindicated if (a) caregivers find invariant manding to be aversive due to its deviation from typical verbal behavior, (b) existing appropriate and adaptive topographical variability in the speaker's behavior is replaced with invariant manding, (c) the repetition-selective effects of FR 1 schedules of reinforcement prevent novel variation in manding corresponding to unplanned changes in activities, events, or stimuli or unexpected changes in the strength of establishing operations for mands, (d) if invariant manding is relatively more vulnerable to challenges to treatment, or (e) if naturally occurring contingencies outside of the treatment environment require occasional topographical variations to contact reinforcement. Therefore, additional research on the effects of lag schedules and other variables that influence mand variability during FCT and their usefulness in addressing these clinical problems are needed.

The current study is the first to assess vocal mand variability during FCT, and to demonstrate that topographical vocal mand variability can be reinforced during FCT. This discovery provides a new lens through which to view assumptions made in existing FCT research. To the best of our knowledge only one prior FCT study controlled for the repetition-selective effects of reinforcement during the differential reinforcement of alternative responding (Adami et al., 2017). Therefore, any outcome of FCT in other cases may have been due to the repetition-selective effect of reinforcement on alternative responding (i.e., the omission of a contingency for variant responding), differential reinforcement of alternative responding, or both. Consequently, future lines of research in FCT could clarify outcomes and underlying behavioral mechanisms by systematically evaluating its effects on variability in both manding and challenging behavior, as well as maintenance, generalization, and recurrence during challenges to treatment (i.e., data on reinstatement, resurgence, renewal of challenging behavior after FCT) when controlling for the repetition-selective or variability-selective effects of differential reinforcement.

The lack of consistent reductions in challenging behavior to clinically significant levels is an important limitation of the current study to address in future research. Independent variant vocal manding under a lag schedule was demonstrated in three participants. Of these three participants, Chris demonstrated zero levels of challenging behavior prior to the observed increase in independent variant vocal manding, and Zahid and Paul continued to demonstrate levels of challenging behavior similar to baseline when initial increases in independent variant vocal manding were observed and throughout the remainder of the treatment evaluation. Close temporal proximity between challenging behavior and manding may have allowed for adventitious reinforcement of challenging behavior. Alternatively, if manding and challenging response topographies belonged to the same operant, and the lag schedule embedded in FCT differentially reinforced independent variant vocal mand topographies, response generalization may have occurred in relation to challenging response topographies. Said differently, reinforcement of the variant dimension of the operant (e.g., Page & Neuringer, 1985) with respect to vocal manding may have spread to the variant dimension of the operant with respect to challenging behavior. Additional research is needed to identify variables that can be manipulated during FCT with lag schedules to eliminate challenging behavior during treatment. However, even if such an outcome is achieved, prior research suggests that differentially reinforcing alternative responding in the treatment of challenging behavior may not only reduce current levels of challenging behavior, and increase alternative responding, but also strengthen persistence of challenging behavior under challenges to treatment (e.g., Mace et al., 2010; a full discussion is beyond the scope of the current study). Therefore, additional research is also needed to determine (a) whether the recurrence or persistence of challenging behavior in relapse contexts after reinforcement of mand variability can be prevented, for example through post-treatment fixed-time reinforcer delivery (Marsteller & St. Peter, 2014) or treatment in alternative contexts (Mace et al., 2010), or (b) if reinforcing mand variability coinciding with the elimination of challenging behavior can prevent recurrence through strengthening the persistence of mand variability during challenges to treatment (e.g., Falcomata & Wacker, 2012).

The results of the current study also raise new questions about the impact of baseline conditions on the effects of FCT with lag schedules. For all participants, the treatment evaluation began with differential reinforcement of challenging behavior on an FR 1 schedule. For three of four participants (i.e., Zahid, William, Chris), this baseline phase was followed by the introduction of FCT + Lag 1 + TD. During baseline, zero or near-zero rates of independent manding were observed. During FCT + Lag 1 + TD, challenging behavior was placed on extinction and the reinforcer for challenging behavior was delivered contingent on prompted and independent variant vocal mand topographies. Despite increasing the length of the TD systematically across sessions, no participants demonstrated increases in independent variant or invariant manding, although prompted variant manding occurred at elevated steady rates for all three participants. In addition, three different patterns of challenging behavior were observed. For Zahid, an immediate decrease in level was observed, followed by a gradual return to baseline rates as the length of the TD increased. For William, a decreasing trend was observed. Alternatively, Chris shifted to an increasing trend. The variables responsible for these differences are unclear. The lack of an increase in independent variant vocal mand topographies was not consistent with prior research (i.e., Silbaugh et al., submitted) which showed large immediate increases in independent variant vocal mand topographies for two children with ASD using a similar procedure. In that study, Lag 1 + TD was introduced on a steady baseline of appropriate manding reinforced on a Lag 0 schedule, not during FCT following baseline reinforcement of challenging behavior as in the current study. In that study, the authors suggested that perhaps the TD provided brief periods of extinction within sessions which evoked topographical variations for selection by the lag schedule. It is possible that in the current study, differential reinforcement of challenging behavior and/or extinction of manding during baseline may have prevented extinction induced mand variability for selection by the lag schedule during FCT + Lag 1

+ TD. Paul's data provide some support for this explanation. For Paul, an immediate, although small, increase in independent variant vocal mand variability was observed when FCT + Lag 1 followed baseline rates of independent variant and invariant manding, as expected based on Silbaugh et al (2016). Given that challenging behavior occurred at fairly stable rates during FCT + Lag 0 for Paul and FR 1 for all other participants, the current results suggest that the effects of FCT with lag schedules may vary as a function of different baseline manding or challenging behavior response rates or rates of reinforcement. Future research could clarify these issues by comparing the effects of different baseline conditions for challenging behavior and manding on responsiveness to FCT + Lag 1 with or without TD.

The lag schedule in the current study represents only one of many possible arrangements. Different arrangements may have different effects on manding and challenging behavior during FCT or recurrence under challenges to treatment, and therefore may serve different purposes in practice. A lag schedule could be arranged to deliver a reinforcer if and only if the first response on a trial is variant relative to the first response evoked on the preceding trial. Alternatively, a lag schedule could be arranged to be delivered if and only if a response varies from the immediately preceding independent response. In the former arrangement, only one response would be eligible for reinforcement each trial, and the reinforcer would be withheld if an invariant response occurred. This arrangement might be more likely to alter topographical variability in the first response emitted on trials, and expand the response class, and might be less likely to alter levels of extinction-induced variability. The latter arrangement, which was used in the current study, allows for multiple responses to be emitted under a brief period of extinction while the experimenter waits for a variant topography. This arrangement might be more likely to alter the relative response strength of response class members, as indicated by changes in extinction-induced variability, and establish or alter a mand response class hierarchy (Baer, 1982) as suggested by Silbaugh et al (submitted). Future research could investigate and compare these different arrangements to determine whether one or the other is more effective as a strategy for preventing the recurrence of challenging behavior under challenges to treatment. Also, both arrangements may be combined in a 2-step treatment sequence. In step 1, using a discrete trial arrangement with reinforcement contingent on the first response being variant, challenging topographies and invariant manding would be placed on extinction or scheduled for punishment. Prompting and prompt fading could be added to expand the response class with additional topographies when challenging behavior and invariant topographies no longer occur. In step 2, reinforcement would be delivered contingent on a response being variant relative to the last response emitted, but not relative to first responses. This 2-step treatment sequence might (a) eliminate challenging behavior and invariant topographies, (b) expand the range of appropriate topographies and promote response generalization, and (c) increase persistence of variant manding under extinction conditions associated with lapses in FCT treatment fidelity.

All participants emitted a variety of independent variant vocal mand topographies regardless of whether experimental control over independent variant manding with the lag schedule was demonstrated. William only independently emitted topographies that were previously prompted. However, in participants for whom experimental control over independent variant manding by the lag schedule was demonstrated (Zahid, Chris, and Paul), a variety of topographies were emitted which were never prompted during the study, and which may be considered novel from a pragmatic perspective. All topographies emitted were contextually appropriate in that their structure corresponded to either public stimuli which both speaker and listener (Skinner, 1957) were in contact with, or interactions with the listener, although not all topographies were grammatically correct. This finding is consistent with prior reports in the literature of increased novel verbal responding under lag schedule conditions (e.g., Brodhead et al., 2016; Contreras & Betz, 2016; Wiskow et al., 2016). Additionally, this finding suggests a potential advantage of programming for variability-selective contingencies during FCT. Specifically, that doing so may facilitate response or stimulus generalization or even promote generative functionally equivalent communication responses across environments by allowing any antecedent stimuli present to evoke contextually appropriate verbal behavior, thereby likely improving the speaker's ability to obtain reinforcement from listeners with appropriate manding despite changes in the environment. Such varied contextually appropriate manding may also (a) be considered a closer approximation to typical language relative to standard FCT practices which limit eligible responses to 1 or 2 different topography- or selection-based mand variants, and (b) may be more resistant to changes in the environment such as fluctuations in establishing operations across different preferred items and activities throughout the day.

Future research could directly evaluate the effects of FCT with lag schedules on the emergence of novel vocal mand topographies.

Multiple other potential limitations of the current study should be noted. First, the current study did not use designs which could rule out the contribution of potential sequence effects on changes in the dependent variables due to the sequential introduction of response prompt fading procedures and lag schedules. Second, some of Chris's reinforced mand topographies may be considered inappropriate vocalizations. However, Pauls' mother approved of the current procedures and all vocalizations were considered an improvement over challenging behavior (e.g., aggression) he regularly engaged in throughout the day with family members. Future research could evaluate the effects of FCT and lag schedules on mand variability when eligible responses are constrained by more conservative criteria (e.g., only instances accompanied by the word "please" and spoken at an ambient volume). Third, demonstration of experimental control by FCT for Chris and Zahid was incomplete. Fourth, the current study did not use a standardized approach to operationally defining a vocal mand topography across participants, the implications of which will need to investigated in future research. It's possible that individualized definitions were necessary to achieve increased levels of topographical mand variability with the lag schedule. The experimenter individually defined "different" topographies based on the manner in which each participant varied vocal topographies under assessment conditions or during baseline reinforcement of challenging behavior under FA conditions or the treatment evaluation. William used only single word vocal utterances, so a definition only required that a single word was different. Chris tended to use three or four word sentences, but those sentences tended to have “please” or “want” in common, and he rarely used only one or two word utterances, so the definition required that at least 2/3 words vary. Paul used one to four or five word vocal utterances, so a response was variant if at least one word was different when subtracting common words from the current utterance and its preceding utterance. For example, if he said “No “ then said “No, I’m busy!” then “I’m still busy!”, the second and third utterances were considered different and therefore variant. The lack of a standardized approach to operationally defining variant mand topographies might have been considered a confound had the definitions been developed under conditions in which a contingency for variant responding was present.

Lastly, FA results suggested multiple functions for William, Zahid’s FA could not rule out multiple functions, and some mands emitted by Paul during reinforcement intervals were impossible to reinforce (e.g., asking the experimenter to leave). However, treatment evaluations targeted only a single function of challenging behavior. Therefore, during reinforcement intervals I could not be certain that consequences functionally related to challenging behavior which differed from the programmed reinforcer, were completely controlled. To enhance the likelihood of obtaining differentiation pertaining specifically to control over behavior by the programmed reinforcer, dependent variables were only measured when the programmed EO was present. A threat to internal validity is unlikely because measurement procedures were held constant across conditions of the treatment evaluation.

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Vita

Bryant Cashious Silbaugh was born in Palo Alto, California, in 1982. He lived with his mother and grandmother in Redwood City, California until 21 years of age. In his senior year, he left high school and began full-time work for a law firm as an administrative assistant. After obtaining his GED, Bryant enrolled in community college in the spring of 2000. In 2003, he declared a major in psychology and accepted admission to the University of California, San Diego. In 2005, he graduated with a Bachelor of Arts in psychology. From 2004 to 2006, he was employed as a laboratory technician at the Molecular and Integrative Neurosciences Department at The Scripps Research Institute in La Jolla, California. In 2008, Bryant received a Master of Arts degree in psychology from San Diego State University after defending his thesis which was later published with the title, “Chemosensory responsiveness to ethanol and its individual sensory components in alcohol-preferring, alcohol-nonpreferring and genetically heterogeneous rats” in the journal Addition Biology. From 2008 to 2013, Bryant provided behavioral intervention to children with autism as a therapist and clinical supervisor in southern California. In 2012, Bryant became a Board Certified Behavior Analyst, and has taught behavior analysis as an online co-instructor with the Florida Institute of Technology since 2013. In the fall of 2013, he entered the Graduate School at the University of Texas at Austin to pursue a PhD in Special Education, and established Trendline ABA, a private practice providing behavioral intervention to children with ASD.

This manuscript was typed by the author.